Black Start Definitions & Procurement Process

PJM State & Member Training Dept.

Objectives

Students will be able to:

- Identify the process and requirements associated with black start generating resources

Critical Load

- Critical load provided by black start
  - Cranking power to critical generation
    - Units with a hot-start time of 4 hours or less
  - Off-site nuclear station light and power (1 feed)
    - Including units off-line prior to disturbance
    - Ensure a “safe” shutdown
  - Critical gas infrastructure
    - Key in quick restoration of the system

Critical Load

- Priority load provided by black start or other generation
  - Off-site nuclear station light and power (2 independent feeds)
    - Facilitate a station “start-up”
  - Cranking power to combustion turbines
  - Power to electric infrastructure
    - Light and power to critical substations
    - Pumping plants for underground cable systems
  - Critical communication equipment
  - Critical command and control facilities
  - Underfrequency load shed circuits

NERC Requirements for Critical Black Start (EOP-005-2)

- The restoration plan shall include:
  - R1.4. Identification of each Blackstart Resource and its characteristics including but not limited to the following: the name of the Blackstart Resource, location, megawatt and megavar capacity, and type of unit
  - R1.5. Identification of Cranking Paths and initial switching requirements between each Blackstart Resource and the unit(s) to be started

NERC Requirements for Critical Black Start (EOP-005-2)

- R6. Each Transmission Operator shall verify through analysis of actual events, steady state and dynamic simulations, or testing that its restoration plan accomplishes its intended function. This shall be completed every five years at a minimum. Such analysis, simulations or testing shall verify:
  - R6.1. The capability of Blackstart Resources to meet the Real and Reactive Power requirements of the Cranking Paths and the dynamic capability to supply initial Loads
  - R6.3. The capability of generating resources required to control voltages and frequency within acceptable operating limits

NERC Requirements for Critical Black Start (EOP-005-2)

- R9. Each Transmission Operator shall have Black Start Resource testing requirements to verify that each Black Start Resource is capable of meeting the requirements of its restoration plan to include:
  - R9.1. Frequency of testing such that each Black Start Resource is tested at least once every three calender years
  - R9.2. A list of required tests:
    - R9.2.1. Ability to start the unit when isolated with no support from the BES or when designed to remain energized without connection to the remainder of the system
    - R9.2.2. The ability to energize a bus
  - R9.3. Minimum duration of each of the required tests

NERC Requirements for Critical Black Start (EOP-005-2)

- R13. Each Transmission Operator and each Generator Operator with a Black Start Resource shall have written Black Start Resource Agreements or mutually agreed upon procedures or protocols, specifying the terms and conditions of their arrangement to include references to the Black Start Resource testing requirements
- R14. Each Generator Operator with a Blackstart Resource shall have documented procedures for starting each Blackstart Resource and energizing a bus

NERC Requirements for Critical Black Start (EOP-005-2)

- R15. Each Generator Operator with a Blackstart Resource shall notify its Transmission Operator of any known changes to the capabilities of that Blackstart Resource affecting the ability to meet the Transmission Operator's restoration plan within 24 hours following such change

NERC Requirements for Critical Black Start (EOP-005-2)

- R16. Each Generator Operator with a Blackstart Resource shall perform Blackstart Resource tests, and maintain records of such testing, in accordance with the testing requirements set by the Transmission Operator to verify that the Blackstart Resource can perform as specified in the restoration plan
  - R16.1. Testing records shall include at a minimum: name of the Blackstart Resource, unit tested, date of the test, duration of the test, time required to start the unit, an indication of any testing requirements not met under Requirement R9
  - R16.2. Each Generator Operator shall provide the blackstart test results within 30 calendar days following a request from its Reliability Coordinator or Transmission Operator

NERC Requirements for Critical Black Start (EOP-005-2)

- R17. Each Generator Operator with a Blackstart Resource shall provide a minimum of two hours of training every two calendar years to each of its operating personnel responsible for the startup of its Blackstart Resource generation units and energizing a bus.
- The training program shall include training on the following:
  - R17.1. System restoration plan including coordination with the Transmission Operator
  - R17.2. The procedures documented in Requirement R14
- R18. Each Generator Operator shall participate in the Reliability Coordinator's restoration drills, exercises, or simulations as requested by the Reliability Coordinator

NERC Requirements for Critical Black Start (CIP-003 thru 009)

- Black Start operations must be conducted in compliance with NERC Critical Infrastructure Standards
- Once defined as a "Critical Cyber Asset," a Black Start unit and its resources must meet the requirements of CIP Standards 003 through 009 to include:
    - Assessing and documenting at least annually the processes for controlling access privileges to protected information
    - A thorough personnel risk assessment
    - Maintaining a procedure for securing dial-up access to the Electronic Security Perimeters
    - Documenting and implementing the technical and procedural controls for monitoring physical access at all access points to the Physical Security Perimeters 24/7

NERC Requirements for Critical Black Start (CIP-003 thru 009)

- NERC CIP Standards apply only to machines that are connected by a routable protocol to the outside world (digital, not analog)

PJM Requirements for Critical Black Start

- Black Start Capable:
  - Designated critical black start generation is identified as such in each Transmission Owners restoration plan
  - Generating unit has the ability of being started and can close an output circuit breaker to a dead bus without energy from other PJM generating units or has a demonstrated ability to operate at reduced levels upon automatic isolation from the grid
  - The generating unit owner and PJM have agreed that the unit should be designated as black start capable
  - The unit is located where black start capability is determined by PJM and all affected TOs to be useful to the restoration process and will be incorporated into the restoration plans of the affected TOs

PJM Requirements for Critical Black Start

- Black Start Capable:
  - The unit must have the ability to close its output breaker to a dead bus within three hours of the request from the local TO or PJM
  - Based on critical load timing requirements, some Black Start resources may be required to adhere to less than a three hour start time
    - These units will be notified of the timing requirement and tested to it during the annual Black Start testing

PJM Requirements for Critical Black Start

- Black Start Performance Standards:
  - Ability to self-start without any outside source of power within three hours, or the time defined in the TOs restoration plan can be demonstrated:
    - Through testing or the ability to operate at reduced levels when automatically disconnected from the grid
  - Ability to close into a de-energized bus can be demonstrated by:
    - Physically closing the generator breaker connected to a dead bus while the unit is running

    or

    - A test that simulates closing the generator breaker while only the generator side of the breaker is energized

PJM Requirements for Critical Black Start

- Black Start Performance Standards:
  - Ability to operate at reduced levels when automatically disconnected from the grid can be demonstrated by:
    - Physically removing the unit from the grid while the unit is running or,
    - A test that simulates removing the unit from the grid
  - Capability to maintain frequency under varying load can be demonstrated by:
    - Picking up an isolated block of load
    - Dynamic off-line testing of the unit's governor controls

PJM Requirements for Critical Black Start

- Black Start Performance Standards:
  - Capability to maintain voltage under varying load can be demonstrated by:
    - Picking up an isolated block of load or,
    - Producing both leading and lagging VARs by varying the voltage setting while the unit is synchronized to the system or,
    - Dynamic off-line testing of the voltage controls
  - Ability to maintain rated output for a duration as identified by the TO's restoration plan
    - Specific gas supply requirements for gas fueled black start units should be considered in the TO's restoration plan such as:
      - Electric feed to gas gate valves
      - Local gas compressors needed to maintain supply

PJM Requirements for Critical Black Start

- Black Start Performance Standards:
  - Each black start generation owner must maintain procedures for the start-up of black start generation at each station
    - These standards shall remain in effect for the duration of the commitment

Defining a Black Start Unit

- PJM defines a Black Start Unit as:
  - A generating unit that has equipment enabling it to start without an outside electrical supply or a generating unit with a high operating factor (subject to Transmission Provider concurrence) with the demonstrated ability to automatically remain operating, at reduced levels, when disconnected from the grid

Defining a Black Start Unit

- NERC defines a Black Start Resource as:
  - A generating unit and its associated set of equipment which has the ability to be started without support from the System or is designed to remain energized without connection to the remainder of the System, with the ability to energize a bus, meeting the Transmission Operator's restoration plan needs for real and reactive power capability, frequency and voltage control, and that has been included in the Transmission Operator's restoration plan

PJM Black Start Unit Requirements

- Must be tested annually
  - To ensure unit can start when requested from a “blackout” state
  - To ensure personnel are familiar with procedure
  - Have the ability to self-start without any outside source of power
  - Have the ability to close unit onto a dead bus within 3 hours of the request to start
  - Have the ability to run for 16 hours, or as defined by TO restoration plan
    - GOs must notify PJM and the TO if a critical blackstart fuel resource at max output falls below 10 hours
  - Have the ability to maintain frequency and voltage under varying load
  - The company must maintain black start procedures for each unit

PJM Black Start Unit Requirements

- Minimum Critical Black Start Requirement for each transmission zone consists of the following components:
  - critical steam cranking power load
    - Steam units with a hot-start time of 4 hours or less (including the load required to supply scrubbers, where necessary)
  - any gas infrastructure critical load in the TO footprint
  - any nuclear station “safe shutdown” power requirements
  - Exceptions or additions to the criteria above will be allowed with PJM approval:
    - SOS-T endorsement will be sought for these exceptions and additions
    - One example could be to address coping power needs for steam units that cannot be supplied by resources other than black start

Required Black Start = 110% (Critical Load Requirement) on a locational basis

PJM Black Start Unit Requirements

- PJM Actions:
  - Will ensure a minimum of two black start resources are “allocated” to each transmission zone with a critical load requirement
    - Black start resources are not required to be physically located within the zone to which they are allocated
  - In collaboration with the TOs, will select Black Start units to meet Critical Load requirements during the 5 year Black Start Selection process described in PJM Manual M-14D, Generator Operational Requirements
  - Will utilize the Black Start Replacement Process, as described in PJM Manual M-14D for changes to Black Start availability or Critical Load requirements that occur within the 5 year period

Black Start Procurement Process

Black Start Unit Procurement

- PJM Actions:
  - In its role as Transmission Operator (TOP), is responsible for selecting the Black Start resources for a system restoration plan.
  - Would work closely with the TOs to identify these units based on:
    - Critical Load requirements
    - Available Black Start resources
    - Minimum number of Black Start resources allocated to a zone
    - Possible cross zonal coordination opportunities
      - Manual 36: System Restoration Attachment A: Minimum Critical Black Start Requirement

Cross Zonal Coordination

- The criteria for this analysis include:
  - Reliability Requirements
    - Procuring sufficient Black Start resources to meet critical load requirements
    - Meeting critical load restoration timing requirements
    - Meeting redundancy requirements
  - Efficiency Opportunities
    - Cost Savings

Black Start Unit Procurement

- PJM Actions:
  - Utilize the start time parameters and test data to evaluate the Black Start resources and whether these resources will meet the requirements of the restoration plans
    - May require some Black Start resources to adhere to less than a 3 hour start time given critical load restoration timing requirements.
      - These units will be notified of this timing requirement and tested to it during annual Black Start testing
    - Recognizes that Black Start resources with three hour start times may not appropriate to meet nuclear power off-site safe-shutdown load restoration requirements. The target restoration time for off-site power to nuclear stations is 4 hours

Black Start Unit Procurement

- Member Actions:
  - Adjust its system restoration plan based on the Black Start units allocated to it from this selection process
  - Has the option of procuring additional Black Start resources (if not already procured by PJM), but the costs of these resources will be recovered, if necessary, outside of the PJM Open Access Transmission Tariff (OATT)
  - Underfrequency Islanding Schemes and Load Rejection Schemes are considered an acceptable alternative to solely maintaining critical black start units, or can be utilized in conjunction with critical black start units as a means to serve critical load during restoration

Black Start Unit Procurement

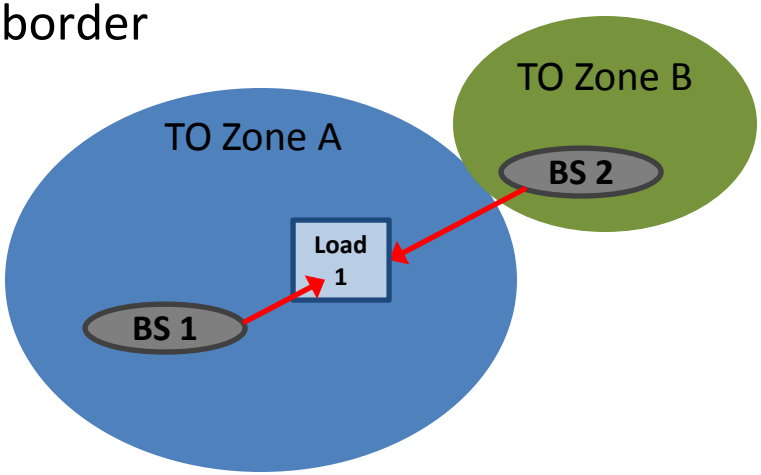
- Member Actions:
  - Should there be a disagreement about the location, amount or number of Black Start resources, or disagreement between the supplying TO, receiving TO or PJM about cross zonal coordination, the following process will be followed:
    - The parties involved would bring the issue to the SOS-T for consultation
    - If the parties continue to disagree, the issue would be referred to the Dispute Resolution Process as detailed in Schedule 5 of the PJM Operating Agreement
    - General notification of initiation and result of Dispute Resolution process will be given to the Operating Committee

Black Start Allocation

- PJM will ensure, at a minimum, an allocation of two Black Start resources to each Transmission zone with a Critical Load requirement
    - Black start resources are not required to be physically located within the zone to which they are allocated (Cross Zonal Coordination)

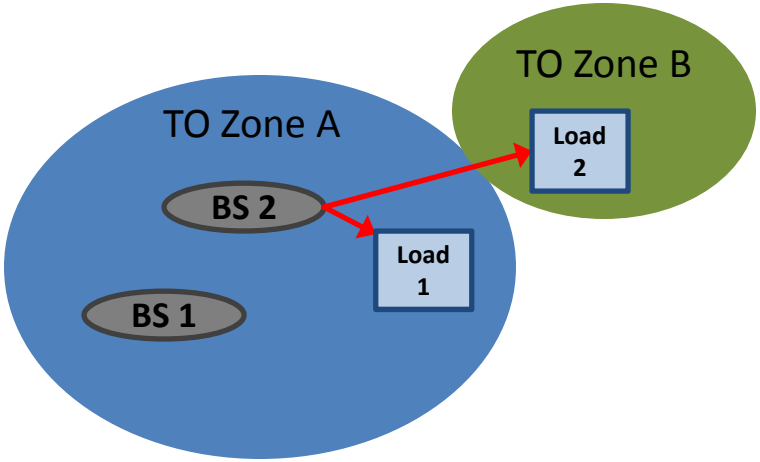
Cross Zonal Coordination

- Level One Cross Zonal Coordination
  - Supplying Black Start generation from outside of a TO zone to meet that zones critical load requirements
  - Both supplier and receiver will document the cranking path to their respective border



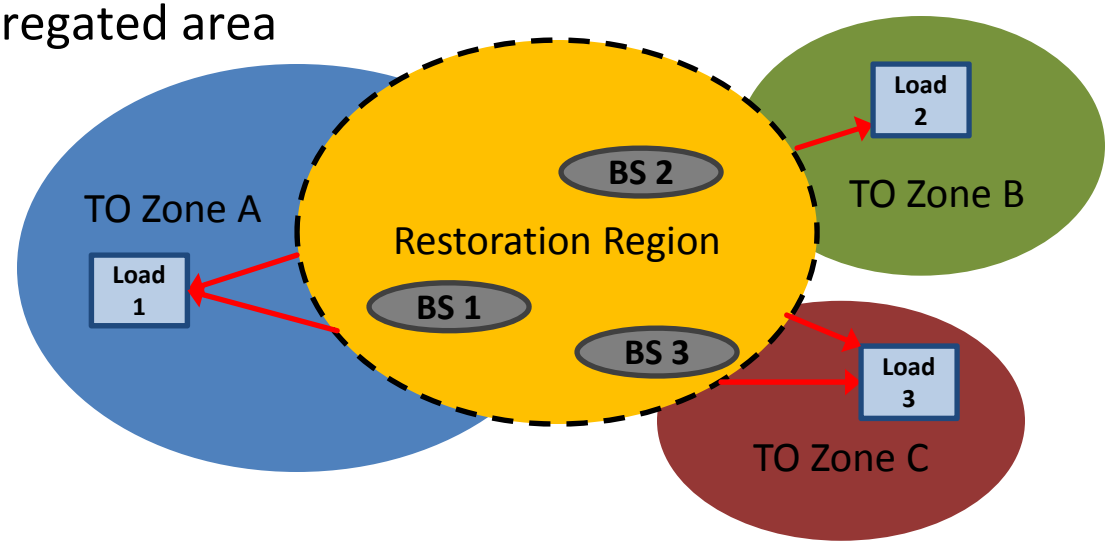
Cross Zonal Coordination

- Level Two Cross Zonal Coordination
  - Supplying Black Start generation to critical and/or customer load pockets across TO zones
  - Both TOs will document this coordination in their restoration plans



Cross Zonal Coordination

- Level Three Cross Zonal Coordination
  - Fully aggregate TO restoration plans into a combined plan for a newly defined Restoration region
  - Merging two or more existing TO zones, only one restoration plan for the aggregated area



Cross Zonal Coordination

- Level One, Two, and Three Cross Zonal Coordination would be pursued to:
  - Eliminate a Black Start shortage within the zone
  - Meet critical load restoration timing requirements
  - Improve restoration speed and/or efficiency
  - Significantly reduce Black Start cost

Cross Zonal Coordination

- Level One/Two Restoration plans:
  - Are on a TO basis, but coordinated between the TOs
  - Cross zonal coordination must be documented in both TO restoration plans
- Level Three Restoration plan:
  - Would involve merging two or more existing TO zones creating a new restoration region
  - One restoration plan for each aggregated area

Resources and References

- PJM. (2013). *PJM Manual 36: System Restoration* (rev. 20). Retrieved from http://pjm.com/~/media/documents/manuals/m36.ashx
- NERC. (2013). *Standard EOP-005-2 – System Restoration from Blackstart Resources*. Retrieved from http://www.nerc.com/pa/Stand/Reliability%20Standards%20Complete%20Set/RSCompleteSet.pdf