System Restoration

Primary Frequency Response

Agenda

- System Restoration
  - Frequency control during normal and restoration operations
  - Review governor modes of operation
  - Review restoration process
  - Reserves during normal and restoration operations

Maintaining Frequency Control

- **During normal operation**, frequency control is very manageable
  - Based on the large amount of generation in service
  - Adequate energy and ancillary services managed through markets
  - Stability of the system due to size of the Interconnection
  - PJM controls generation via telemetered or verbal instructions to Generation Owners (GOs) / MOC Dispatchers

Maintaining Frequency Control

- **During a restoration process**, frequency control is more challenging
  - Based on the small amount of generation in service
  - Potentially multiple small islands within PJM footprint
  - Instability of the system due to low system inertia
  - Transmission Owners control generation via direct communication to GOs / MOC Dispatchers

Maintaining Frequency Control

- Manual 36, System Restoration
  - Section 6.1.7 Blocking Governors
    - During a restoration process, **governors must not be blocked** and plant operators must operate the generator in a mode which **allows the governors to respond freely to frequency deviations** if this mode of control is available
    - Generating units which cannot meet this criteria **do not contribute to Dynamic Reserves**

Black Start Units

- Critical Black Start Units
  - Are first units to be brought online
    - Compensated under Schedule 6A of PJM OATT to provide "Black Start Service" and tested on an annual basis
  - Can be started without any external power
  - Must be able to maintain frequency in **Isochronous mode**
  - Supply start up (cranking) power to Critical Load units
  - Must be able to switch to normal (parallel) droop mode

Critical Load Units

- Critical Load Units
  - Units that have a **hot start time of 4 hours or less** as defined in Manual 36, System Restoration, Attachment "A"
    - Hot Start-up Time (from PJM Markets Gateway User Guide)
      - The time interval, measured in hours, from the actual unit start sequence to the breaker close for a generating unit in its hot temperature state
  - This is not the same designation of "Critical" as defined by NERC
    - NERC defines critical assets and critical cyber assets in the context of the Critical Infrastructure Protection (CIP) standards
    - The designation of Critical Load Units is not related to NERC CIP standards

Isochronous Control

- Isochronous Control refers to a governor droop setting of 0%
- Used by Black Start units during system restoration
  - Frequency is controlled, through governor action alone, to the target value of the governor (60 Hz)
  - Response is rapid and sensitive to even small changes in frequency
  - No external (AGC) signal involved – only local frequency
- Concerns
  - Most effective for a single unit serving an isolated block of load, or when the unit is the only unit responding to changes in load
  - Only one unit can be in the isochronous mode during a restoration

Dynamic Reserve

- From Manual 36, System Restoration, Section 5.1.2
  - Needed to ensure that the system, or islands within the system, will remain stable following the loss of the largest energy contingency which can be:
    - Single generator
    - Transmission path from a generation facility
  - Consists of two components:
    - Generator reserve that is available **via governor action**
    - System load with **automatic under-frequency trip** levels
  - Concern:
    - Loss of generation at 57.5 Hz

Dynamic Reserve

- 25% to 30% of PJM load is served by feeders equipped with automatic under-frequency relay controls
  - Dynamic Reserves are only calculated and used during system restoration
  - Determined by “load pick-up” factors for units paralleled to the system
    - Maximum load a generator can pick up, as a percentage of the generator’s rating (capacity), without incurring a frequency decline below safe operating levels
    - 5% for steam units (Including Combined Cycle Units)
    - 15% for hydroelectric units
    - 25% for combustion turbines
    - Or, the unloaded capacity of the unit

Summary

- Importance of PFR during restoration, and in calculating Dynamic Reserve
- These concepts have been an essential part of PJM's training and operational expectations for many years
- PJM Package B would ensure PFR for all generation in system restoration plans
  - Would not apply to units not used during restoration (i.e. wind, solar, nuclear)

Questions?