

System Restoration

Primary Frequency Response

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- - 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
 - <u>PJM controls generation via telemetered or verbal instructions to Generation</u> <u>Owners (GOs) / MOC Dispatchers</u>



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
 <u>Dispatchers</u>



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



- - 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, <u>through governor action alone</u>, 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

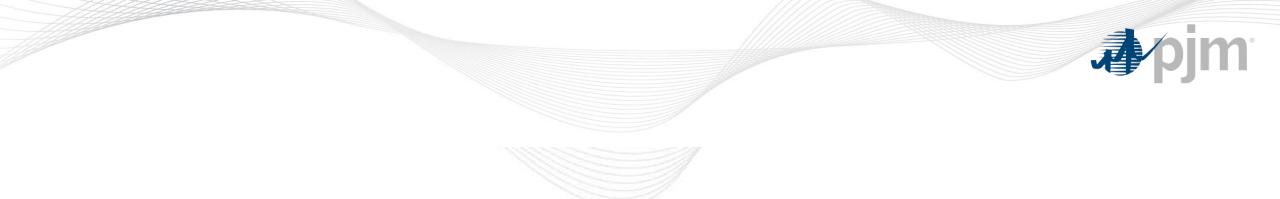


Dynamic Reserve

- 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



- 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?

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