Working to Perfect the Flow of Energy

Reserve Calculations

Reserve Terminology

- Synchronized Reserve (a.k.a. Spinning Reserve)
  - Increase in output energy level of a synchronized generator which can be attained in 10 min.
    - Or decrease in a Load Response Resource
  - Max energy output achieved in 10 min by a unit operating as a synchronous condenser
  - Maintained in real-time via Synchronized Reserve Market
- Quick-start Reserve
  - Not synchronized to system
  - Includes maximum energy output level of a unit that can be attained in 10 min. from the PJM request
  - Generally run-of-river hydro, combustion turbines, combined cycle and diesel type units

- Primary Reserve (a.k.a. Contingency Reserve)
  - Synchronized Reserve + Quick Start Reserve
  - All MW available within 10 minutes
- Secondary Reserve (a.k.a. Supplemental Reserve)
  - The reserve capability that can be fully converted into energy in >10 to 30 minute interval following a request by PJM
  - Equipment does not need to be synchronized to the system

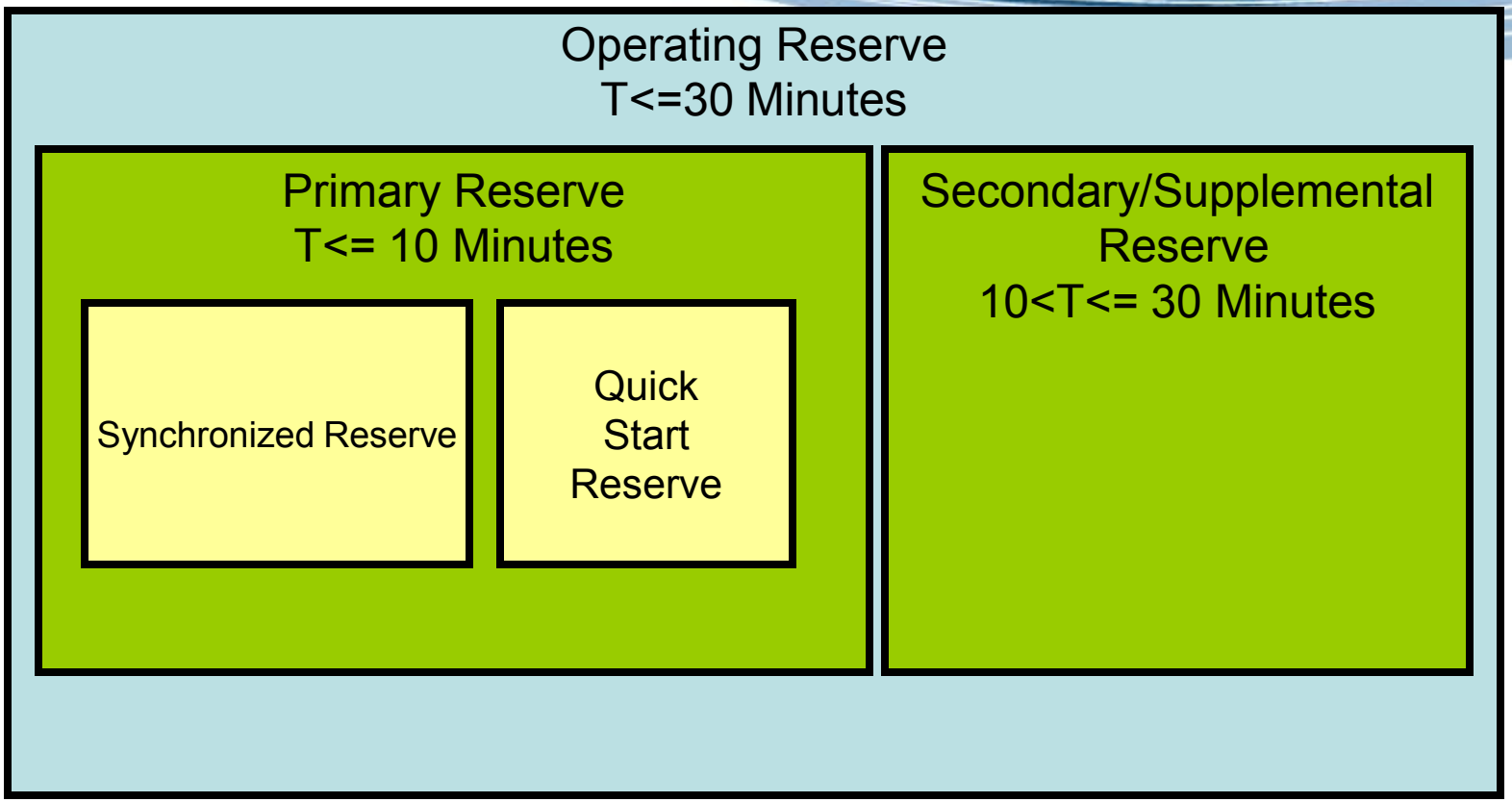
- Day-ahead Scheduling Reserve (a.k.a. Operating Reserve)
  - Generation available from either offline or online units within 30 minutes
  - Scheduled to meet Operating Reserve requirements in DA Market and Reserve Adequacy (RA) Run
    - Market for Day-ahead Scheduling Reserve began 6/1/08
  - Not required to be maintained in real-time
  - Primary Reserve + Secondary Reserve

- The following are NOT included in the current EMS or Tier 1 reserve calculations:
  - Pumped Storage in pumping mode (monitored separately)
  - Nuclear Units
  - Wind Units
  - Units logged as “Testing”, “Failed to Start”, “Tripped” or “Unavailable”
  - Online CTs that are generating
    - For CTs, only condensing units are included in reserve calculations
  - Demand Response Resources
    - Included in Tier 2 Synchronized Reserve and DA Scheduling Reserve Market
  - Reserves from implementation of Emergency Procedures
    - i.e. Max Emergency, Voltage Reduction, Interchange curtailments, Public Appeal for reduction, Shared Reserve Agreements

- The reserve calculations depend on accurate generation data in the following areas
  - Unit Limits
    - Specifically the Synchronized Max and Economic Max Limits
  - Ramp rates
    - Specifically the Synchronized Reserve Ramp Rate
  - Notification Time
  - Start-up Time
  - Ambient temperature adjusted limits

- The following Reserve categories will be eliminated:
  - Normal Regulating Reserve
  - Beyond Secondary
- The following Reserve categories will be consolidated into Synchronized Reserve:
  - Synchronized Reserve – Regulating Units
  - Synchronized Reserve – Non-regulating Units
  - Regulation Assignment will be subtracted from Synchronized Reserve total in calculation
    - Same MWs can not be counted as Regulation and Synchronized Reserve
- Intent is to simplify calculations to improve data quality
- Changes will be made to EMS and eDART IRC prior to Shortage Pricing Implementation

Reserve Categories

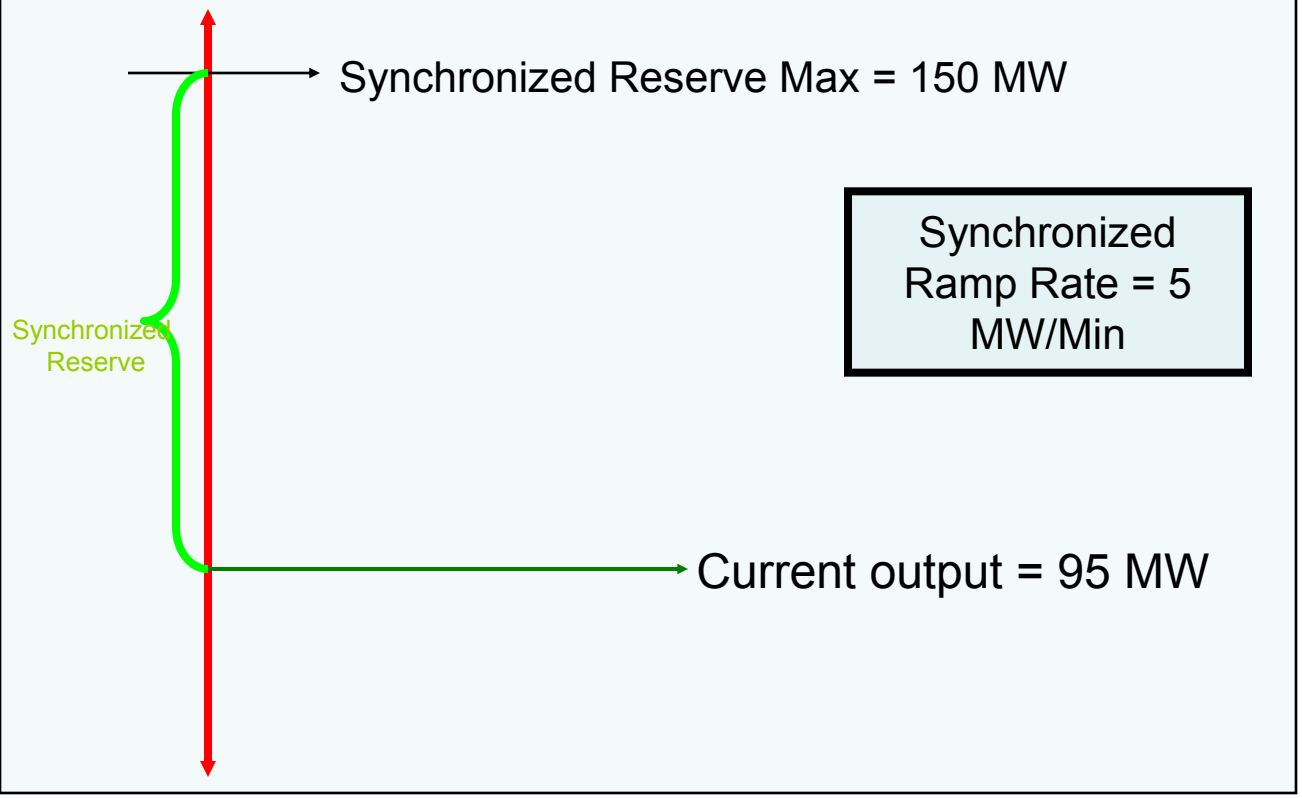


- Synchronized Reserve
  - Lesser of:
    - (Spin Ramp Rate * 10 minutes)
    - Synchronized Max limit – current output

If no Synchronized Reserve Maximum limit is specified in eMKT, the Economic High limit is used.

- Synchronized Reserve

EXAMPLE



Synchronized Reserve = lesser of
- (5 MW/min *10 Min) = **50 MW**
- 150(Synchronized Max) – 95(Current Output) = **55 MW**

Synchronized Reserve = 50 MW

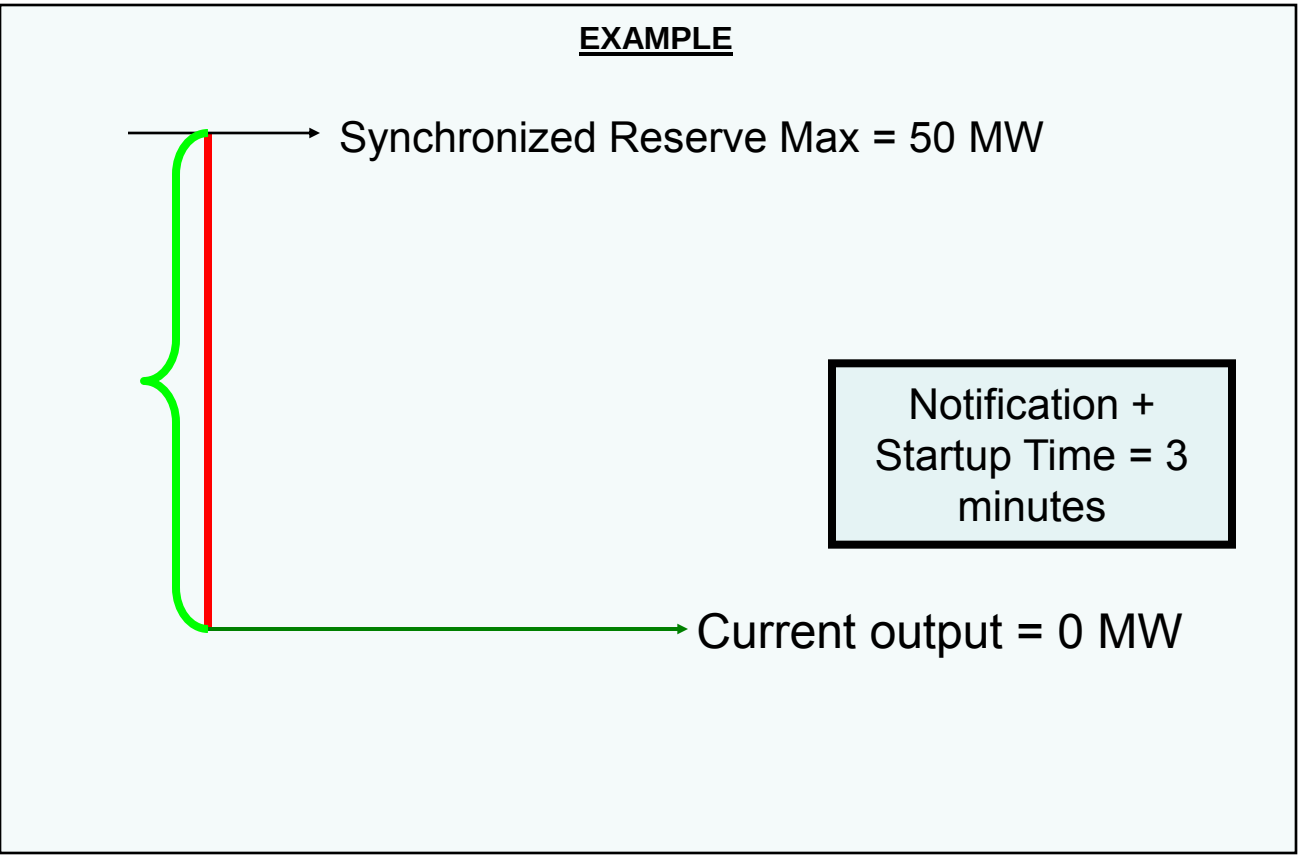
Limited by Synchronized Ramp Rate

- Quick Start Reserve
  - Generation available within 10 minutes for Offline reserve unit
    - Synchronized Maximum Limit
      - » Limited by Ramp Rate * (10 – Time to Start)

Time to Start = Notification time + Startup Time

Only offline units that have a (Notification time + Startup Time) <= 10 minutes are included in the calculation

- Quick Start Reserve



Quick Start Reserve =
- Synchronized Max = 50 MW

Quick Start Reserve = 50 MW

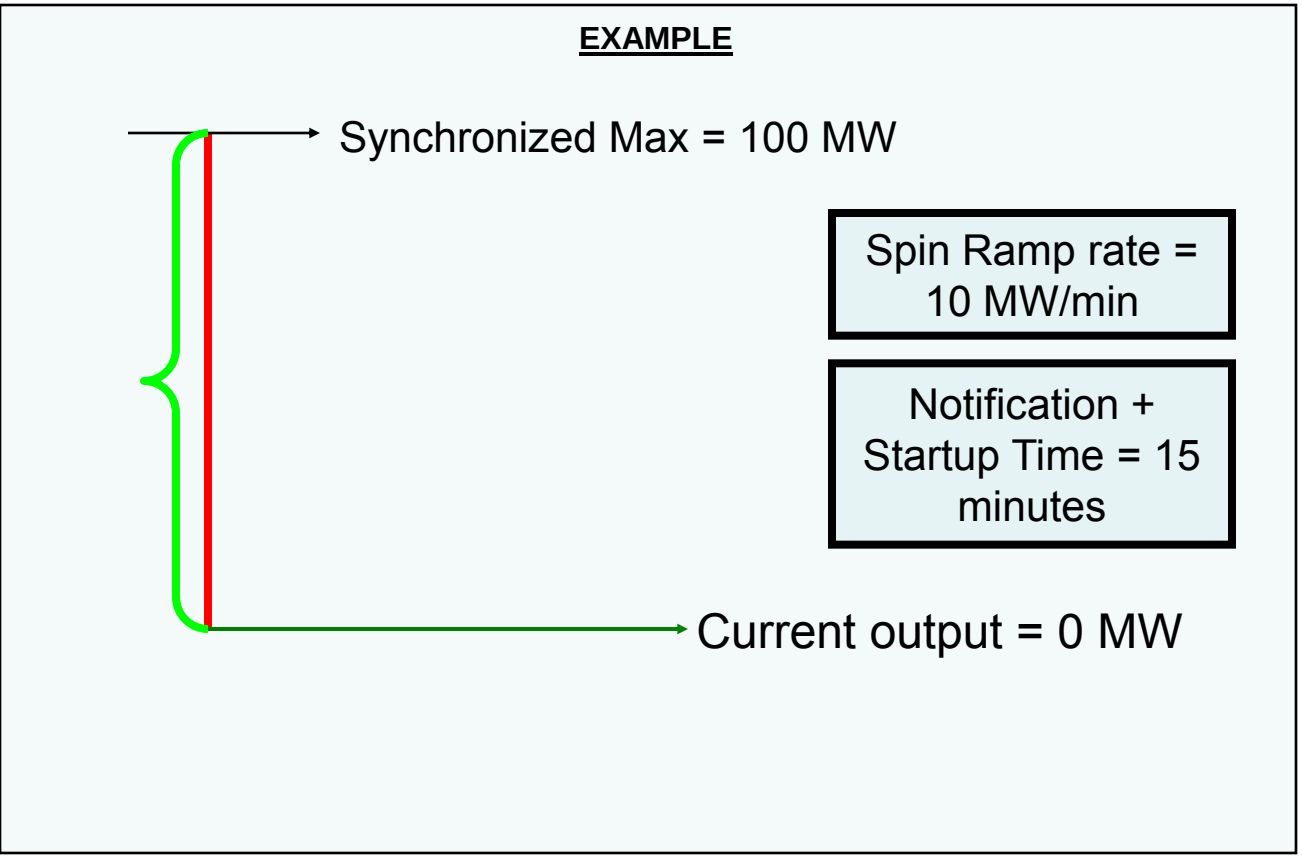
- Operating Reserve
  - Generation available within 30 minutes from Offline or Online reserve units
    - Operating Reserve = Offline + Online
  - Offline
    - Synchronized Maximum Limit
      - » Limited by Ramp Rate * (30 – Time to Start)

Time to Start = Notification time + Startup Time

Only offline units that have a (Notification time + Startup Time) <= 30 minutes are included in the calculation

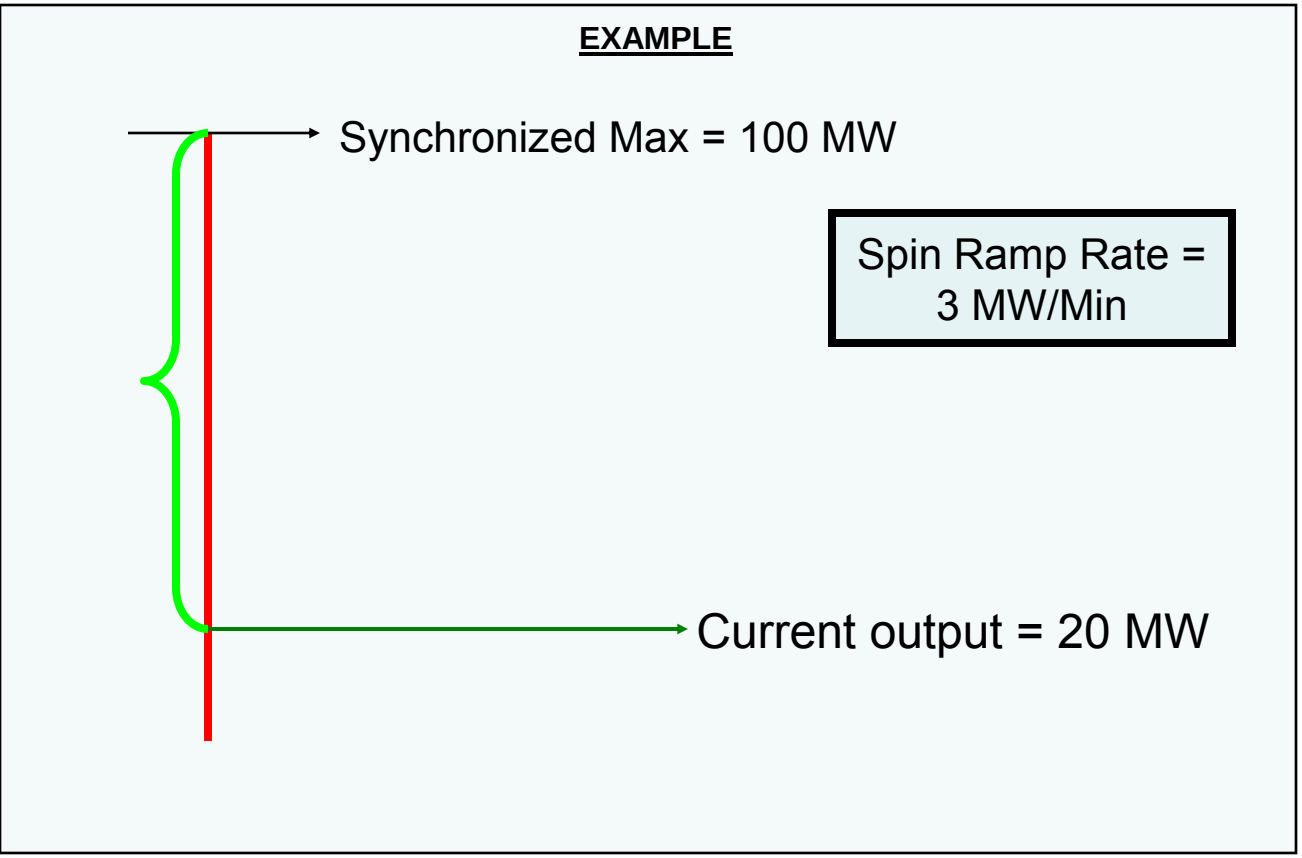
- Operating Reserve
  - Generation available within 30 minutes from Offline or Online reserve units
    - Operating Reserve = Offline + Online
  - Online
    - Lesser of
      - Spin Ramp rate * (30 minutes)
      - Synchronized Maximum Limit – Current MW level

- Operating Reserve – Offline Unit



Operating Reserve = 100 MW

- Operating Reserve Online Unit



Operating Reserve =
- 3 MW/min * (30 Min) = 90 MW
- Synchronized Max – Current MW = 100 – 20 = **80 MW**

Operating Reserve = 80 MW

Limited by Synchronized Max

- Secondary/Supplemental Reserve
  - Generation available within 10-30 minutes
    - Secondary Reserve = Operating Reserve – Primary Reserve

EMS Reserve Monitor

Display View Overlay Tools Help

Empower SPECTRUM | Reserve Monitor Overview

Zonal Report PRINT | Unit Res | Gen IRC | RTO Over | Online Units Only OFF

Reserve Category	RTO	RFC	Mid Atlantic Eastern	Mid Atlantic Total	South	West	NI	VACAR Reserves
Normal Reg. Res.	783	754	442	526	29	98	130	0
Primary	3994	2726	1253	1777	1268	832	117	
Total Spinning	2479	1980	587	1031	499	832	117	
Spin N Reg	2189	1720	539	972	469	651	97	
Spin Reg	290	260	48	59	30	181	20	
Quick Start	1515	746	666	746	769	0	0	
Secondary	11947	11228	3986	5553	719	3586	2089	
Operating	15941	13954	5239	7330	1987	4418	2206	
Beyond Secondary	18104	15793	3196	4923	2311	5720	5150	
Pump Trip	0	0	0	0	0	0	0	
Max Emergency	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
Spinning Alarm		1300	0	896		0	0	
Primary Alarm		2000		1700	423	0	0	
GPM Spinning	1421	1162	329	543	259	369	250	
Spinning Delta	-1212	-1022	-304	-549	-190	-478	5	
GPM Primary	2936	1908	995	1289	1028	369	250	
Primary Delta	-1212	-1022	-304	-549	-190	-478	5	

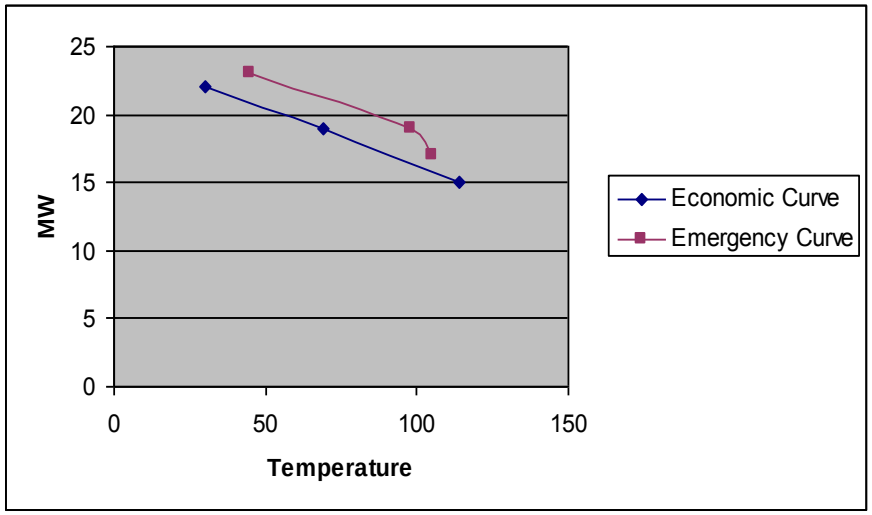
- When reviewing historical data (from 8/8/07 and other days) and operating situations, it is evident that the data quality of the existing generator operating and market parameters needs to be improved
  - What was expected based on unit data did not match actual situation
  - Data not being updated consistently
  - Reliability and Economic implications

- Synchronized Reserve Ramp Rate
  - Can be higher than Energy Ramp Rate
  - May not be physically achievable by generating units
  - Leads to overstating of reserves
- Difference between Synchronized Reserve Max and Economic Max
  - Synch Max >= Eco Max
  - Synch Max <= Emerg Max
  - Units appear reluctant to exceed Economic Max during Synch Reserve events
  - Leads to overstating of reserves

Data Critical for Reserve Calculations

- Synchronized Reserve Ramp Rate (MW/Min)
  - Used in calculation of Synchronized and Operating Reserve
  - Can be changed daily
- Unit limits
  - Specifically Synchronized Reserve Max Limit
    - Economic Max <= Synch Reserve Max <= Emergency Max
    - Can be changed hourly
- Startup Time
  - Used to determine eligibility for Quick Start and Operating Reserve
  - Can be changed daily
- Notification Time
  - Used to determine eligibility for Quick Start and Operating Reserve
  - Can be changed hourly (to accommodate staffing issues)

- Increased interaction/feedback from plant operators
  - Get the data from the plant to PJM!
  - Automated updating (Dominion)
  - Data needs to be based on physical unit characteristics
- Utilize eMKT Weather Data Curves for CT limits



- Better monitoring/situational awareness by Gen Operators
  - Can utilize eMKT Dispatch Lambda screen to see current unit data being utilized
  - Update hourly values as required in eMKT
  - Notify PJM Operations of known data problems
- Technology Updates
  - New IRC reporting format scheduled for development in eDART
  - Generation Performance Monitoring Tool
    - Rolled out in 2009
    - Some performance problems being worked on

- PJM also calculating on EMS Synchronized Reserve and Primary Reserve utilizing:
  - GPM-adjusted Ramp Rates
  - Economic Max Limits
- Provides for a more conservative reserve calculation for comparison with normal calculations

- The following events should NOT trigger Shortage Pricing by themselves
  - Loading of Synchronized or Quick Start Reserves (i.e. unit loss)
  - Implementation of Shared Reserves
  - Transaction Ramping out of PJM
- In most cases, these are transient events and not true Shortage situations
  - However, if coupled with peak load conditions, these type of events could initiate a reserve shortage