Experiences of PJM and Other US Markets in a Deregulated Environment

What has worked and what are the challenges?

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• Day-Ahead Energy Market
• Real-Time Energy Market
• Capacity Market
• Financial Transmission Rights Auctions
• Gas/Electric Market Coordination

Ancillary Services Markets
• Regulation
• Synchronized Reserves
• Day-Ahead Scheduling Reserves
• Black Start Services
• Reactive Services
What has worked and what are the challenges?

**Successes**
- Increased Operational Efficiency / Congestion Management
- Increased Competition
- Efficient Entry and Exit
- Promoting Innovation
- Capacity Market (PJM)
- Demand Response / Alternative Resources

**Challenges**
- Transmission Cost Allocation
- Resource Adequacy
- Gas/Electric Market Coordination
- Market Boundary Issues
PJM Market Expansion – A Case Study

AEP / Dayton / Commonwealth Edison Integration into the PJM Market

Key Study Conclusions:

• Bilateral Trading could only achieve 40% of the efficiency gains of LMP-based market
• Incremental benefit of LMP Market Integration = $180 Million annually, Net Present Value over 20 yrs is $1.5 Billion

Referenced with Permission: Source: Erin T. Mansur and Matthew W. White, “Market Organization and Efficiency in Electricity Markets,” March 31, 2009, Figure 2, pg 50, discussion draft.
Managing a Sea-Change

Cleared Installed Capacity

- Coal
- Gas
- Nuclear
- Renewables
- Demand Response & Energy Efficiency

Delivery Year


ICAP (MW)

70,000 60,000 50,000 40,000 30,000 20,000 10,000 0
Transitioning from Coal to Gas

2009 to Date: 28,000 MW in Retirement Notices
PJM Forward Capacity Market, 2007-2015

**Demand Resource Additions**
- Energy Efficiency
- Demand Response Offered
- Interruptible Load for Reliability
- Active Load Management
- Committed/Cleared DR

**Cumulative Generator Capacity Additions**
- CT/GT
- Combined Cycle
- Diesel
- Hydro
- Steam
- Nuclear
- Solar
- Wind
- Fuel Cell

RPM Implemented
PJM Market – Average Power Generation Emissions
Pounds Per MWh of Electricity Produced

PJM Average Emissions (lbs/MWh)

- Carbon Dioxide
- Sulfur Dioxides
- Nitrogen Oxides
Natural Gas System & Resources in Eastern Interconnection

Legend:
- Gas Storage Point
- Major Gas Lines (38" or more)
- Gas Lines (24" or more)
- Shale Gas Plays
- Shale Gas Basins

Zones:
- ERCOT
- NYISO
- FRCC
- MISO
- ISO-NE
- PJM
- SERC
- EKPC
- SPP

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**Issue:**
Timely gas nominations are due at **12:30pm EPT** the day before (Day 1).
Electric “awards” are made at **4pm EPT** the day before (Day 1) 3.5 hours later; actual gas flow occurs starting at **10am EPT** on Day 2

*Source: NERC report on Gas Electric Interdependency*
Fuel Cost Adjusted LMP
(referenced to 1999 fuel prices through September 2013)
Evolution of Supply

• Traditional resources  
  Less flexible
• Renewable resources  
  Intermittent
• Less capability to provide power grid services

Evolution of Demand

• Technology enabled flexibility
• Alternative resource growth
• Enhanced capability to provide grid services

Market Evolution

• Improvement in optimization and control systems
• More real-time markets to reward consumer flexibility
• Development of Forward Demand Response Control Signals
Advanced Market Systems

- Industry Leadership
- Customer Focused
  eLoad Response
- Technology
  Resource Control Application
  Time-coupled Optimization
- Business Resiliency
  - Security
  - Dual Control Centers
Evolution of Demand

• Trends
  – Increase in customer commitment to curtail demand during high price periods
  – Smart Grid Technology deployment
  – Retail rate innovation

• Operational Implications
  – Increase in customer response to price
  – Aggregated demand resources providing high quality grid services
  – Increasing operational confidence in DR performance
Evolution of Alternative Resources

- **Storage**
  - Stationary Battery
    - Ancillary Service supply
    - Integration with intermittent resources
  - Water Heaters
  - Compressed Air
  - Electric Vehicles

- Integrated renewable resource and building management systems

- Integrated distributed resources
• Nearly 25% of synchronous reserves are provided by DR
• DR revenues grew from around $1.4 million in 2002 to over $1 Billion annually
Demand Response Impact

Probable Load Curve without DR

Load Drop from Emergency DR Resources

www.pjm.com
Laurel Mountain
Wind Farm
98 MW
61 turbines
Battery Storage
Lithium-ion (A123)
Power 32 MW, Energy 8 MWh

Grid-Scale Energy Storage System – 32 MW Battery
Aggregated Demand Resource Response to Synchronized Reserve Event

Aggregation 13,078 Residential Customers

10 Minute Ramp In Period

Wireless Integrated Control Platform

Curtailed Load Event graph

9.36 MW