DOE Workshop: Load Participation in Capacity and Ancillary Services Markets

Terry Boston
President & CEO
PJM Interconnection
October 26, 2011
• 24% of generation in Eastern Interconnection
• 27% of load in Eastern Interconnection
• 19% of transmission assets in Eastern Interconnection

20% of U.S. GDP produced in PJM

As of 7/21/2011

<table>
<thead>
<tr>
<th>KEY STATISTICS</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PJM member companies</td>
<td>710+</td>
</tr>
<tr>
<td>millions of people served</td>
<td>58</td>
</tr>
<tr>
<td>peak load in megawatts</td>
<td>158,450</td>
</tr>
<tr>
<td>MWs of generating capacity</td>
<td>180,400</td>
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<tr>
<td>miles of transmission lines</td>
<td>61,200</td>
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<tr>
<td>GWh of annual energy</td>
<td>794,335</td>
</tr>
<tr>
<td>generation sources</td>
<td>1,365</td>
</tr>
<tr>
<td>square miles of territory</td>
<td>211,000</td>
</tr>
<tr>
<td>area served</td>
<td>13 states + DC</td>
</tr>
<tr>
<td>Internal/external tie lines</td>
<td>142</td>
</tr>
</tbody>
</table>
“Improving energy efficiency in the buildings-and-appliances and industrial sectors could (assuming substantial barriers can be addressed) offset some 85 percent of the projected incremental demand for electricity over the next 25 years.”


“Electricity conservation has come of age and it is less expensive to save electricity than to use it. New light bulbs and other electricity-saving devices will reduce power consumption [growth] by 80 to 90 percent—eliminating the need for new power plants and requiring the closure of many existing ones.”

Business Week, 1984

Offers of Demand-Side Resources as Capacity in PJM by Delivery Year

- Start RPM Capacity Market

- Energy Efficiency
- RPM and FRR DR
- Interruptible Load for Reliability
- Active Load Management

As of 7/2011
PJM Incremental Capacity Resource Additions

<table>
<thead>
<tr>
<th>Year</th>
<th>Net Increase in Energy Efficiency Capacity</th>
<th>Net Increase in Demand Resource Capacity</th>
<th>Increase in Generation Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/2012</td>
<td>16%</td>
<td></td>
<td></td>
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<tr>
<td>2012/2013</td>
<td>77%</td>
<td></td>
<td></td>
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<tr>
<td>2013/2014</td>
<td>64%</td>
<td></td>
<td></td>
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<tr>
<td>2014/2015</td>
<td>60%</td>
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As of 6/22/2010
Demand Resource in the Capacity Market-2014/2015

Demand Resources

14,118 MW or enough power for 5 million people or half the number of households in the state of Michigan

Energy Efficiency

822 MW or enough to power 149,000 households about the number of households in the city of Cleveland, Ohio
With diversified technologies participating in the program, it has become an open window to demonstrate PJM’s continuous efforts and great achievements in building an innovative company.

Summer 2011

Shake and Bake
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

⭐ Data Source:
Power grid frequency data collected by FDRs (Frequency Disturbance Recorder)

⭐ Event Description:
This video shows the effects of a 1600 MW generator trip caused by the East Coast Earthquake on 8/23/2011. During this earthquake, two nuclear reactors at the North Anna Power Station in Mineral, Virginia were automatically taken offline. As a result, the frequency in the Eastern Interconnection dropped to 59.93Hz.
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

FNET Data Display [9/23/2011 Generator Trip]
Time: 17:51:11 UTC  59.9984 Hz

From UT  Current F-net
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

FNET Data Display [8/23/2011 Generator Trip]
Time: 17:51:12.4 UTC  59.9939 Hz

From UT  Current F-net
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

From UT  Current F-net
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

FNET Data Display [9/23/2011 Generator Trip]
Time: 17:51:14.4 UTC 59.9679 Hz

From UT Current F-net
August 23, 2011 Earthquake Near Richmond VA

From UT  Current F-net
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

From UT Current F-net
August 23, 2011 Earthquake Near Richmond VA

Event Replay of 8/23/2011 East Coast Earthquake

From UT Current F-net
Summer 2011---How Hot Was It?
The only sustainable competitive advantage is the ability to learn faster than the competition.
Partnering for load frequency control with loads and storage.
Grid-Scale Energy Storage System – 1 MW Battery

Operational Details
• Lithium-ion nano titanate (Altairnano)
• Power 1 MW, Energy 250 kWh
• Full capacity duration, 15 minutes
• Efficiency, 90% round trip (AC-AC)
• Usable Charge Range, 5%-99%
• 2 years, 280,000 cycles, < 2% degradation
What am I?

480,000 Vehicles in United States
Average ~66 miles per day
MPG = ~7
Parked 12 hours at same location
Parked for 3 months

Available for a full time summer job.
Electric resistance water heater demonstrates low-cost water heating using day-ahead LMP while responding to the PJM frequency regulation signal.

Operational Details
• 105 gallon, dual element electric resistance
• “Power” 4.5 kW, Energy 26 kWh
PJM pilot water heater -- January 14, 2011; Midnight to 3:00 a.m.

- PJM Frequency Regulation Signal
- Water heater power consumption +/- 2.25 Kw base point
Electric Thermal Storage: Space Heaters

- Vcharge Inc. controlling ETS units in 30 homes
  - Stroudsburg, PA
- Could save each household 6 – 9 cents/kWh if controlled for energy purchasing and Regulation
- 14,000 units deployed in PPL in 1980’s
Operational Details
- Lithium-ion, 18650 cells ("laptop batteries")
- Power 19.2 kW, Energy 35 kWh
- Full capacity duration, 1.8 hours
- Efficiency, 80-85% round trip (AC-AC)
- Usable Charge Range, 5%-99%

Mid-Atlantic Grid Interactive Car Consortium
Vehicle-to-Grid Demonstration

- Each vehicle capable of 19.2 kW. Actual average capacity ~12 kW
- First demonstrated October 2007
- Currently aggregating five vehicles in Delaware
More Reg down during these hours means increasing state of charge.
Pony Under the Christmas Tree?

60¢ (PJM Off-peak Price)

75¢ per “Gallon”
General Motors, OnStar: Large-scale aggregation

Frequency Regulation
Percent Renewables
Locational Marginal Prices

PHASE 2
Additon of Residential Owned Volts

OnStar

Managed Charging
Frequency Response

PHASE 1
1,000 Volt OnStar Laboratory Simulation
ENBALA’s Power Network (EPN)
Operational Performance – Aggregation of 16 water pumps:
How many black dots?

Still a matter of perspective
I like meters…
…but they cannot meter “Negawatts”
Union Station — 1908

FIRE, GREATEST OF DISCOVERIES
ENABLING MAN TO LIVE IN VARIOUS CLIMATES
USE MANY FOODS AND COMPEL THE
FORCES OF NATURE TO DO HIS WORK

ELECTRICITY, CARRIER OF LIGHT AND POWER
DEVOURER OF TIME AND SPACE, BEARER
OF HUMAN SPEECH OVER LAND AND SEA
GREATEST SERVANT OF MAN, ITSELF UNKNOWN

THOU HAST PUT ALL THINGS UNDER HIS FEET