Introduction to Aurora

22nd Annual Electric Market Forecasting Conference
Luxor Hotel, Las Vegas, NV
AGENDA

Aurora Overview
Core Offering
Technical Demo
Aurora Overview

• Established in 1997

• Customer focused development
  • User experience
  • Expert software support
  • Training included in the license
PROVEN

IRP Utilities

Regulators & Planning Authorities

Traders, IPPs, Developers

Research & Consultants
<table>
<thead>
<tr>
<th>How is Aurora Used?</th>
<th>Generation Planning/Budgeting</th>
<th>Trading Support</th>
<th>Transmission Planning</th>
<th>Market Assessment/Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Integrated resource planning</td>
<td>• Short term analysis (often nodal)</td>
<td>• Frequency and value of constraints</td>
<td>• Zonal &amp; Nodal price forecasting (hourly &amp;/or sub-hourly)</td>
</tr>
<tr>
<td></td>
<td>• Budget projections</td>
<td>• FTR analysis</td>
<td>• Production cost impacts</td>
<td>• Scenario based and probabilistic</td>
</tr>
<tr>
<td></td>
<td>• Detailed generator analysis</td>
<td>• Highly automated (e.g. data feeds)</td>
<td>• Infrastructure studies</td>
<td>• Risk &amp; Portfolio analysis</td>
</tr>
<tr>
<td></td>
<td>• Assess RPS and environmental policies</td>
<td></td>
<td></td>
<td>• Market design and policy analysis (CPP)</td>
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</table>
Aurora Overview

• Modeling Approach
• Unified Functionality
• Attributes
• Usability
• Speed
• Integration and Automation
• Insightful Reporting
# Modeling Approach

<table>
<thead>
<tr>
<th>Chronological</th>
<th>Price Forecasts</th>
<th>Objective Function</th>
<th>Developed Using .NET</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Price forecasting simulation as hourly or sub-hourly</em></td>
<td><em>Based on market fundamentals</em></td>
<td><em>Minimize the system’s total production cost</em></td>
<td><em>Offers seamless integration with Microsoft &amp; other products: SQL Server, Excel, XML, zipped XML, etc.</em></td>
</tr>
</tbody>
</table>
Unified Functionality

- Market Price Forecasts
- Risk Modeling
- Integrated Nodal Capability
- Portfolio Analysis & Optimization
- Aurora Regional Database
- Long-term Capacity Expansion
- Co-optimized Ancillary Services
- Hourly Chronological Dispatch Simulation
- RPS and Emission Constraints
Attributes

- Usability
- Speed
- Performance & Granularity
- Integration & Automation
- Insightful Reporting
**Speed**

- Spend time analyzing results

### Run Time Breakdown

- Writing output run time
- Initial simulation setup run time
- Hourly data resolve run time
- Hourly setup run time
- Daily setup run time
- Unit commitment logic run time
- LP solve for dispatch run time
- Storage scheduling run time
- General post processing run time

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>RUN TIMES</th>
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<tbody>
<tr>
<td>PJM ISO-NE (27 zones, 7554 resources)</td>
<td>&lt; 3 minutes</td>
</tr>
<tr>
<td>Eastern: MISO PJM (Nodal) ~75,000 buses</td>
<td>&lt; 2 hours</td>
</tr>
<tr>
<td>ERCOT (8 zones, 568 resources)</td>
<td>~ 1 minute</td>
</tr>
<tr>
<td>ERCOT (Nodal) 7,108 buses</td>
<td>&lt; 19 minutes</td>
</tr>
<tr>
<td>WECC (16 zones, 3652 resources)</td>
<td>&lt; 2 minutes</td>
</tr>
<tr>
<td>CAISO (Nodal) 4,724 buses</td>
<td>~ 20 minutes</td>
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</table>
Integration & Automation

Automation + Efficiency = Competitive Advantage

Web Scraper & Scripting
- Automatically import data from external or internal sources
- Aurora scripts / .Net
- Schedule multiple projects to run automatically

Computational Datasets (CDS)
- Dynamic calculation of variables during a study
- Automate large data sets for scenario analysis

Productivity Tools
- DB Compare tool
- Link data
- Time Series tables: Annual, Monthly, Daily, Hourly, Generic
Integration & Automation

Custom/Proprietary Data

Reports, Graphs, Custom Query Results, GIS View, etc.

Output DB (xmpSQL, SQL Server, mySQL, XML)

Aurora Input DB (xmpSQL, SQL Server, XML)

Other Custom Input (.xls, Web Scraper, etc.)
Insightful Reporting

**Annual Avg MCP, Base, Expected & 95% CI $/MWh**

- **Zone A**
- **Zone B**

**Quick View files:**
- Maintain custom charts, graphs, pivot tables, queries & reports
Core Offering – One Tool
Core Offering – One Tool

- Aurora Databases
- Resource & Constraint Modeling
- Long Term Capacity Expansion (LTCE)
- Risk Analysis
- Portfolio & Portfolio Optimization
- Maintenance
- Nodal Analysis
Aurora Databases
Aurora Databases

• U.S. & Canada, Europe, Mexico
• Included in the license
• Updated throughout the year and released when completed
• Data documentation
• Includes a 30-year forecast base
• Extensive testing and calibration!
Flexibility to Quickly Customize Footprint

ERCOT

PJM & MISO

Western Interconnect

Eastern Interconnect
Detailed Resource Elements

- Conventional
  - Min-up & down times, start costs, must-run
  - Operating rules, nomograms, resource dependencies
  - Constraints: Fuel, Emissions, Energy

- Load Modifying Resources
  - Energy efficiency & demand response

- Renewables
  - Hourly solar & wind profiles

- Hydro
  - Flexible, composite reservoir

- Storage: pumped, battery
  - Optimize to expected price or demand
Modelling Constraints
Energy, Emissions, RPS, Capacity & Fuel

- Hourly, daily, monthly, seasonal & annual constraints
- Useful for modeling environmental policy limits
- Short-term & long-term studies
Integrated Post Processing Tool

• Resources
  • All types – including conservation & demand response
  • Partial ownership, recognizes outages, emissions

• Contracts
  • Over 30 different contract types

• Results
  • Total Net Portfolio Cost & Energy
  • Market Sales & Purchases
  • Detailed Resource & Contract reports
  • Portfolio Emissions & RPS
Portfolio Optimization

What new resources are viable? How do they perform with uncertainties? Which options are best for our company?

LT Capacity Expansion

Entire Market

Risk

Iterations

Portfolio Optimization

Single Entity
Efficient Frontier

Capability to perform portfolio optimization using:

• Risk-reward framework
• A linear optimization model
Long Term Capacity Expansion
Economic Additions & Retirements

New Resources Input
- Candidate resources by Aurora area
- Standard resource characteristics
- Annual Max & Overall Max
- RPS

Future Assumptions
- Fuel
- Load Growth
- Emissions
- Transmission
- Planning Reserve Margins
- Ancillary Services

Results
- New Resource Additions
- Economic Retirements
- Capacity Prices
- Standard Output
LTCE Results

• Expansion plan
• Incremental MW by technology
• Resource Modifier Table (RMT)
• Resource additions
• Retirement schedules
• Capacity prices
• Insightful diagnostics
• Resource value (NPV or RLV)
• Screening curve
Risk Analysis
Capture & Quantify Uncertainty

Monte Carlo or Latin Hypercube

Core Hourly Algorithms

Input Variables
- Zonal Demand
- Portfolio Demand
- Fuel
- Hydro
- Transmission
- Random Resource Outage
- Generic Risk Variables

Distribution Types
- Normal & LogNormal
- Binomial & Uniform

Risk Settings
- Mean
- Standard Deviation
- Positive and Negative Correlations

Results
All Selected Output Reports
Maintenance
Automated Scheduling
Creates a Maintenance Schedule

• Schedules maintenance:
  • To maximize daily reserve margin for the zone/pool (where plant located)
  • Over plant’s maintenance cycle

• Settings include:
  • Schedule Maintenance
  • Maintenance Cycle
  • Maintenance Length
  • Maintenance Priority

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<tr>
<th>ID</th>
<th>Name</th>
<th>Maint Begin Date</th>
<th>Maint End Date</th>
<th>Maint Begin Hour</th>
<th>Maint End Hour</th>
<th>Outage Factor</th>
<th>Zone or Pool Name</th>
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<td>5/27/2018</td>
<td>1</td>
<td>24</td>
<td>100</td>
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</tr>
</tbody>
</table>
Nodal Analysis

- SCOPF solution
  - Generalized N-x contingencies
  - Contingency islanding
- Supports sub-hourly dispatch
- Dynamic calculation of nodal losses
- Planned/unplanned resource outages
- DC line and phase shifter optimization
- RTO seams modeling options for faster calibration!
Nodal Datasets

• Ready to run for:

  - Generation fully mapped to ISO-delivered power flow cases
  - Generator details including:
    • Heat rate curves, emissions, wind shapes, etc.
  - Includes defined hubs, significant corridors and contingencies
Display Results
Play with Product
Galleria A

Wed 1 pm to 5 pm
Thu 8:30 am to 5 pm
Fri 8:30 am to 2 pm
Technical Demonstration
Thank you