SERVM
Strategic Energy Risk Valuation Model

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11/10/2016
Topics

- Resource Adequacy Overview
- SERVM Model Overview
- Reserve Margin Study (2013)
- Renewable Integration Study (2015)
  - Effective Load Carrying Capability
  - Flexibility Study
  - Integration Costs
Resource Adequacy Overview
Resource Adequacy

- **Resource Adequacy Definition:** The ability of supply-side and demand-side resources to meet the aggregate electrical demand (NERC Definition)

- **Resource Adequacy Studies**
  - **Reserve Margin Study**
    - Goal: Calculate generating capacity deficiencies and determine the amount of capacity needed to maintain resource adequacy during peak conditions
    - Purpose: Input into expansion planning processes
  - **Effective Load Carrying Capability Study**
    - Goal: Determine the capacity contribution of intermittent resources
    - Purpose: Necessary to calculate the system reserve margin
  - **Flexibility Study**
    - Goal: Determine reliability deficiencies including both firm load shed events and renewable resource curtailment due to system ramping/startup constraints (not capacity deficiencies)
    - Purpose: Provides assistance in setting appropriate parameters for resource additions and to determine system operating reserve requirements
  - **Integration Cost Study**
    - Goal: Determine incremental system costs caused by adding intermittent resources
    - Purpose: Used in capacity procurements and in resource selection processes
Resource Adequacy Metrics

- **Loss of Load Expectation (LOLE\textsubscript{CAP}):** Expected number of firm load shed events in a given year due to capacity shortfalls
- **Loss of Load Expectation (LOLE\textsubscript{FLEX}):** Expected number of firm load shed events in a given year due to not having enough ramping capability

- **Loss of Load Hours (LOLH\textsubscript{CAP}):** Expected number of hours of firm load shed in a given year due to capacity shortfalls
- **Loss of Load Hours (LOLH\textsubscript{FLEX}):** Expected number of hours of firm load shed in a given year due to not having enough ramping capability

- **Expected Unserved Energy (EUE\textsubscript{CAP}):** Expected amount of firm load shed in MWh for a given year due to capacity shortfalls
- **Expected Unserved Energy (EUE\textsubscript{FLEX}):** Expected amount of firm load shed in MWh for a given year due to not having enough ramping capability
SERVM Model Overview
Strategic Energy Risk Valuation Model (SERVM)

- SERVM has over 30 years of use and development
- Probabilistic hourly and intra-hour chronological production cost model designed specifically for resource adequacy and system flexibility studies
- SERVM calculates both resource adequacy metrics and costs
SERVM Uses

- **Resource Adequacy**
  - Loss of Load Expectation Studies
  - Optimal Reserve Margin
  - Operational Intermittent Integration Studies
    - Penetration Studies
    - System Flexibility Studies
  - Effective Load Carrying Capability of Energy Limited Resources
    - Wind/Solar
    - Demand Response
    - Storage
  - Fuel Reliability Studies
    - Gas/Electric Interdependency Questions
    - Fuel Backup/Fixed Gas Transportation Questions
  - Transmission Interface Studies

- **Resource Planning Studies**
  - Market Price Forecasts
  - Energy Margins for Any Resource
  - System Production Cost Studies
  - Evaluate Environmental/Retirement Decisions
  - Evaluate Expansion Plans
Resource Commitment and Dispatch

- 8760 Hourly Chronological Commitment and Dispatch Model
- Simulates 1 year in approximately 1 minute allowing for thousands of scenarios to be simulated which vary weather, load, unit performance, and fuel price
- Capability to dispatch to 1 minute interval
- Respects all unit constraints
  - Capacity maximums and minimums
  - Heat rates
  - Startup times and costs
  - Variable O&M
  - Emissions
  - Minimum up times, minimum down times
  - Must run designations
  - Ramp rates
- Simulations are split across multiple processors linked up to the SQL Server
Resource Commitment and Dispatch

- Commitment Decisions on the Following Time Intervals allowing for recourse
  - Week Ahead
  - Day Ahead
  - 4 Hour Ahead, 3 Hour Ahead, 2 Hour Ahead, 1 Hour Ahead, and Intra-Hour
- Load, Wind, and Solar Uncertainties at each time interval (decreasing as the prompt hour approaches)
- Benchmarked against other production models such as PROSYM

1 - 4 Hour Ahead Forecast Error

At hour 0, SERVM draws from correlated load, wind, and solar forecast error distributions for intra-hour, 1 hr ahead, 2 hrs ahead, 3 hrs ahead, and 4 hrs ahead uncertainty. SERVM then makes commitment & dispatch adjustments based on the uncertain forecast, but ultimately must meet the net load shape that materializes.

Current Position: t = 0
Ancillary Service Modeling

- **Ancillary Services Captured**
  - Regulation Up Reserves
  - Regulation Down Reserves
  - Spinning Reserves
  - Non Spinning Reserves
  - Load Following Reserves

- **Co-Optimization of Energy and Ancillary Services**
  - Each committed resource is designated as serving energy or energy plus one of the ancillary services for each period
SERVM Framework

- **Base Case Study Year**
  - Weather (35 years of weather history)
    - Impact on Load
    - Impact on Intermittent Resources
  - Economic Load Forecast Error (distribution of 5 points)
  - Unit Outage Modeling (thousands of iterations)
    - Multi-State Monte Carlo
    - Frequency and Duration

- Base Case Total Scenario Breakdown: 35 weather years x 5 LFE points = 185 scenarios
- Base Case Total Iteration Breakdown: 185 scenarios * 100 unit outage iterations = 18,500 iterations

- Reserve Margin Study/ELCC Study: Hourly Simulations
- Flexibility and Integration Cost Studies: Intra Hour Simulations
Reserve Margin Study (2013)
Load Modeling: Summer Peak Weather Variability
2013 Reserve Margin Study

Year

% From Normal Weather

PNM-North
PNM-South

Renewable Shapes: 30 + Years
2013 Reserve Margin Study

![Wind and Solar Capacity Factor Graphs]

- **Wind**: Graph showing average capacity factor by hour of day and month.
- **Solar**: Graph showing average capacity factor by time of day and month.
Using CBO GDP approach and assuming 30% multiplier for electric load growth compared to GDP growth

<table>
<thead>
<tr>
<th>Load Forecast Error Multipliers</th>
<th>Probability %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.95</td>
<td>2.7%</td>
</tr>
<tr>
<td>0.97</td>
<td>14%</td>
</tr>
<tr>
<td>0.99</td>
<td>23.8%</td>
</tr>
<tr>
<td>1.00</td>
<td>19.1%</td>
</tr>
<tr>
<td>1.01</td>
<td>23.8%</td>
</tr>
<tr>
<td>1.03</td>
<td>14%</td>
</tr>
<tr>
<td>1.05</td>
<td>2.7%</td>
</tr>
</tbody>
</table>
Unit Outage Modeling

- **Full Outages**
  - Time to Repair
  - Time to Failure

- **Partial Outages**
  - Time to Repair
  - Time to Failure
  - Derate Percentage

- **Startup Failures**

- **Maintenance Outages**

- **Planned Outages**

- **Created Based on NERC GADS Data**
Multi State Frequency and Duration Modeling vs Convolution
BA = PNM + Tri-State Regions
Committed and Dispatched as a single region

PNM - Four Corners
PNM ownership of PV 1-3, FC 4-5, SJ 1-4

PNM - North
Reeves 1-3, Rio Bravo, Valencia, Renewables

PNM - South
Afton CC, Lordsburg1, Lordsburg 2, PNM portion of LUNA 1

El Paso Electric

Tri-State North

Public Service Company of Colorado

Southwestern Public Service Company

Arizona Entities (APS, AEPCO, TEP, Salt River Project, Gila River Power Station)
Demand Response

<table>
<thead>
<tr>
<th></th>
<th>Power Saver Program</th>
<th>Peak Saver Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (MW)</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>Season</td>
<td>June-Sept</td>
<td>June-Sept</td>
</tr>
<tr>
<td>Hours Per Year</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Hours Per Day</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Firm load shed to maintain reserves equal to 4% of load
LOLE_{CAP} and LOLH_{CAP} Results
2013 Reserve Margin Study

Events averaged 2 hours
Industry Standard: 1 day in 10 year standard = 0.1 LOLE = 21% reserve margin
2013 Reserve Margin Study

"Total Reliability Costs = CT Carrying cost + Production Costs above a CT + Purchases above a CT + Unserved Energy Costs"

Graph showing the relationship between Total Reliability Costs and Reserve Margin.
Renewable Integration Study: Effective Load Carrying Capability Study
Incremental Effective Load Carrying Capability
Generic Example Only

- Simulate Base Case:
  - $\text{LOLE}_{\text{CAP}} = .20$

- Add 50 MW Incremental Wind
  - $\text{LOLE}_{\text{CAP}} = .19$

- Add 50 MW GT Capacity
  - $\text{LOLE}_{\text{CAP}} = .15$

- Wind Resource reduced LOLE by 0.01 while GT resource reduced LOLE by 0.05

- $\text{ELCC} = .01/.05 = 20\%$

- Incremental ELCC can also be approximated by calculating average output during EUE events.

- Average ELCC is calculate by removing entire wind portfolio and then adding it back to understand its LOLE reduction compared to GT Resources
EUE and Renewable Profiles by Hour of Day
2015 RIS Study

- Wind Profile by hour of day (Secondary Axis)
- PV Profile by hour of day: (Secondary Axis)
- PV Tracking by hour of day (Secondary Axis)
<table>
<thead>
<tr>
<th></th>
<th>PV Fixed</th>
<th>PV SAT</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2018 average</strong></td>
<td>47.2%</td>
<td>62.1%</td>
<td>21.9%</td>
</tr>
<tr>
<td><strong>2018 incremental</strong></td>
<td>43.0%</td>
<td>57.2%</td>
<td>14.2%</td>
</tr>
<tr>
<td><strong>2023 average</strong></td>
<td>46.9%</td>
<td>61.2%</td>
<td>21.7%</td>
</tr>
<tr>
<td><strong>2023 incremental</strong></td>
<td>38.9%</td>
<td>52.1%</td>
<td>13.7%</td>
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</tbody>
</table>

SAT: Single Axis Tracking
Renewable Integration Study: Flexibility Study
What Does the Flexibility Problem Look Like?

Possibility of Adequate Total Capacity, but Inadequate Ramping Capability. Results in $\text{LOLE}_{\text{FLEX}}$ event.
Increase Load Following Reserves to Reduce LOLE$^{\text{FLEX}}$ Events

Over Commit Conventional Resources and Increase Curtailment, but Avoid LOLE$^{\text{FLEX}}$
Flexibility Study Approach

- Identify LOLE\textsubscript{FLEX} events and renewable curtailment (overgen) events
- Solve the deficiencies using the following approaches and calculate costs:
  - Change operating procedures (i.e. raise load following requirement)
  - Swap or add existing capacity with flexible capacity (multiple technologies)
### Base Case Physical Reliability Results

#### Varying Operating Reserve Levels

#### 2015 RIS Study

- **2018: 16% Reserve Margin**
- **Spin + Reg Requirement = Varied from 8% to 16% of Load**
- **LOLE\textsubscript{CAP}** is near previous LOLE study which did not take into account flexibility problems
- **LOLE\textsubscript{FLEX}** adds more events but are extremely low in magnitude and in duration (<10 min)
- **10%- reg + spin target is likely reasonable given the size and duration of the LOLE\textsubscript{FLEX}**

<table>
<thead>
<tr>
<th>2018 Study Year</th>
<th>Reg + Spin Target 8% of Load</th>
<th>Reg + Spin Target 10% of Load</th>
<th>Reg + Spin Target 12% of Load</th>
<th>Reg + Spin Target 16% of Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018 LOLE\textsubscript{CAP}</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td>2018 LOLE\textsubscript{FLEX}</td>
<td>7.15</td>
<td>0.74</td>
<td>0.07</td>
<td>0.03</td>
</tr>
<tr>
<td>2018 Curtailment MWh</td>
<td>21,246</td>
<td>23,708</td>
<td>32,178</td>
<td>118,189</td>
</tr>
<tr>
<td>System Production Cost M$</td>
<td>289.04</td>
<td>294.09</td>
<td>301.02</td>
<td>322.35</td>
</tr>
</tbody>
</table>
LOLE_FLEX Across Different Operating Reserve Requirements
2015 RIS Study

Note: Largest decrease in LOLE_FLEX moving from 8% of Load to 10% Reg + Spin target. Slight benefit thereafter
Production Costs Across Different Operating Reserve Requirements
2015 RIS Study
Renewable Curtailment Across Different Operating Reserve Requirements
2015 RIS Study

![Graph showing renewable curtailment across different operating reserve requirements. The x-axis represents the Reg + Spin Target (% of Load) ranging from 6% to 18%, and the y-axis represents Renewable Curtailment (MWh) ranging from 0 to 350,000. Two lines are shown: one for 2018 and one for 2023. The lines indicate an increase in renewable curtailment as the target increases.](image-url)
## Base Case (Monthly Basis)

### 2015 RIS Study

<table>
<thead>
<tr>
<th>Month</th>
<th>$\text{LOLE}_\text{CAP}$</th>
<th>$\text{LOLE}_\text{FLEX}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>Feb</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Mar</td>
<td>-</td>
<td>0.21</td>
</tr>
<tr>
<td>Apr</td>
<td>-</td>
<td>0.17</td>
</tr>
<tr>
<td>May</td>
<td>-</td>
<td>0.07</td>
</tr>
<tr>
<td>Jun</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Jul</td>
<td>0.10</td>
<td>0.01</td>
</tr>
<tr>
<td>Aug</td>
<td>0.05</td>
<td>0.01</td>
</tr>
<tr>
<td>Sep</td>
<td>0.00</td>
<td>0.03</td>
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<tr>
<td>Oct</td>
<td>-</td>
<td>0.08</td>
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<tr>
<td>Nov</td>
<td>-</td>
<td>0.04</td>
</tr>
<tr>
<td>Dec</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>Total</td>
<td>0.21</td>
<td>0.74</td>
</tr>
</tbody>
</table>
Integration Cost Study
2018 Wind Integration Cost Adder Calculation

- **Simulate Base Case:**
  - $LOLE_{CAP} = .21; LOLE_{FLEX} = .07$

- **Add 50 MW Incremental Wind/Remove 6.5 MW CT (.13 ELCC * 50 MW):**
  - $LOLE_{CAP} = .21; LOLE_{FLEX} = .20$

- **Add Reserve MW until $LOLE_{FLEX} = .07**
  - Additional Reserves = 4 MW

- **Calculate System Cost Impact of Additional 4 MW Reserves**
  - System Cost = +$794,161

- **Divide by Renewable Energy**
  - Integration Cost Adder = $794,160 / 133,152 MWh = $5.96/MWh
## 2018 Integration Cost Results

<table>
<thead>
<tr>
<th>Technology</th>
<th>Incremental Gen (MWh)</th>
<th>Required Spin Increase to Maintain Base Case Reliability</th>
<th>Cost Increase</th>
<th>$/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>WIND</td>
<td>133,152</td>
<td>4 MW</td>
<td>794,161</td>
<td>5.96</td>
</tr>
<tr>
<td>PV</td>
<td>108,011</td>
<td>15% of Incremental Solar Output</td>
<td>489,772</td>
<td>4.53</td>
</tr>
<tr>
<td>PV SAT</td>
<td>126,144</td>
<td>15% of Incremental Solar Output</td>
<td>489,772</td>
<td>3.88</td>
</tr>
</tbody>
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