Renewable Integration: Quantifying the Effects of Variable Energy Resources

Wind and Solar Integration Summit
Scottsdale, Arizona

Presented by:
Judy Chang

January 24, 2011
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Examination of Integration Issues

Quantifying Regulation Need

Case Study of Balancing 50,000 MW of Variable Generation Resources

Important Consideration when Estimating Operational Needs
Renewable generation is expected to grow significantly over the next 15-20 years

- A 20% renewable penetration by 2025 would require over 150 GW of renewable capacity
- Out of 150 GW, about **100 GWs** would likely come from wind generation
- Significant capacity are also expected from various biomass and geothermal sources
- ~10 GW are expected to come from concentrated solar and photovoltaics (PV)

**Significant environmental and fuel diversity benefits accompany renewable energy usage.**

**To realize those benefits, some changes to our existing electric system and markets / grids operations are necessary.**
Adding significant new wind and solar resources requires new operational processes

- Effects of using large volumes of variable generation require new operating methods
  - **Variability of wind and solar** can be significantly larger than that of load especially when resource diversity is not significant
  - **Reduced usage of existing generation** while needing them more for reserves or regulation
- As FERC is requesting, these may involve intra-hour scheduling and increased coordination across balancing areas

Source: California ISO Study of Operational Requirements and Market Impacts at 33% RPS

**Load Duration Curves With and Without Solar and Wind Penetration**

Comparison of hourly duration curves for load and “load-net-of-wind and solar” shows that the net load factor could decrease significantly
What are the most relevant renewable integration topics?

FERC, in its January 2010 Notice of Inquiry, identified the following topics:

- Data and forecasting
- Scheduling flexibility and incentives
- Day-ahead market participation and reliability commitments
- Balancing authority coordination
- Reserve products and ancillary services
- Capacity markets
- Real-time adjustments

In the November 2010 NOPR, FERC focuses on the above highlighted topics, specifically:

- Intra-hour scheduling
- Use of best available variable generation forecasts
- Generator regulation service

The rest of the presentation focuses on Generator Regulation Service
Of the operational services, FERC NOPR focuses on “Generator Regulation Service”

♦ What is “Regulation Service?”
  • Every system defines the service slightly differently, for example:
    ■ Intra-5-minute variations served by generators on Automatic Generation Control
    ■ Intra-10-minute load variations, typically served by specific generators
  • The time period used for the definition will affect the magnitude of service need

♦ RTOs use markets to determine the price and costs of regulation
♦ Some transmission owners use cost-based methodologies to set charges for customers
♦ FERC proposes a new Schedule 10 transmission service to quantify and pay for “generator regulation needs”
  • FERC asks the rate to remain the same as the existing regulation service
  • This leaves the quantity to be determined by the transmission operators
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Important Consideration when Estimating Operational Needs
A simple and adjustable method for quantifying Regulation need

**Data Input**
- Installed variable generation
- Detailed load & generation profiles
- Forecast errors for load & generation

**Simulation**
Calculations using **statistical parameters** that describe characteristics of VER and load

**Output**
Regulation and load-following need
Case Study: Integration of 50 GW of New Wind Generation to Satisfy 25% RPS requirement on a 100 GW system

Estimate the Regulation and Load Following needs for a hypothetical system:
♦ Base Year (2011) Peak Load of 100 GW
♦ Annual Load Growth of 0.8%
♦ Base Year VER capacity of ~ 3 GW
♦ Study Year (2025) incremental VER capacity of 50 GW

Load characteristics:
• Statistics of load forecast errors and load variability
• Load growth

Variable generation characteristics
• Statistics of forecast errors and output variability
• Effects for generation output across diverse sites
• Relationship between load and generator variability

Regulation requirement can be estimated with two components of variance of load and generation, we refer them as:
• Average forecast error
• Intra-period volatility
Case Study: Integration of 50 GW of New Wind Generation to Satisfy 25% RPS requirement on a 100 GW system

### INPUT ASSUMPTIONS

#### Load Characteristics

<table>
<thead>
<tr>
<th>COMPOSITE LOAD PARAMETERS</th>
<th></th>
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<th></th>
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<tbody>
<tr>
<td>BASE YEAR</td>
<td>2011</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>STUDY YEAR</td>
<td>2025</td>
<td></td>
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<tr>
<td>Annual Load Growth Factor</td>
<td>0.80%</td>
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<table>
<thead>
<tr>
<th>Season</th>
<th>1 Std Dev Load Forecast Error (MW)</th>
<th>1 Std Dev Load Variability (MW)</th>
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<tbody>
<tr>
<td>Spring</td>
<td>2011</td>
<td>2025</td>
<td>2011</td>
<td>2025</td>
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<tr>
<td>Summer</td>
<td>179</td>
<td>201</td>
<td>78</td>
<td>88</td>
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<td>Fall</td>
<td>179</td>
<td>201</td>
<td>80</td>
<td>90</td>
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<tr>
<td>Wintr</td>
<td>179</td>
<td>201</td>
<td>88</td>
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#### Generation Characteristics

<table>
<thead>
<tr>
<th>COMPOSITE VER PARAMETERS</th>
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<tbody>
<tr>
<td>BASE YEAR</td>
<td>2011</td>
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<td></td>
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<tr>
<td>STUDY YEAR</td>
<td>2025</td>
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<td></td>
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<tr>
<td>Base Year VER Capacity</td>
<td>3,251 MW</td>
<td></td>
<td></td>
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<tr>
<td>Study Year VER Capacity</td>
<td>53,251 MW</td>
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<table>
<thead>
<tr>
<th>Season</th>
<th>1 Std Dev of Forecast Error (% of CAP)</th>
<th>1 Std Dev of Within 5-min Variability (% of CAP)</th>
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<tbody>
<tr>
<td>Spring</td>
<td>1.2%</td>
<td>0.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>0.6%</td>
<td>0.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>0.5%</td>
<td>0.3%</td>
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<tr>
<td>Wintr</td>
<td>0.8%</td>
<td>0.2%</td>
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### RESULTS

#### REGULATION (MW)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Incremental</th>
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<tbody>
<tr>
<td>SPRING</td>
<td>2,080</td>
<td>1,312</td>
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<tr>
<td>SUMMER</td>
<td>1,395</td>
<td>590</td>
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<tr>
<td>FALL</td>
<td>1,284</td>
<td>511</td>
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<td>WINTER</td>
<td>1,543</td>
<td>752</td>
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#### LOAD FOLLOWING (MW)

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<th>Total</th>
<th>Incremental</th>
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<tbody>
<tr>
<td>SPRING</td>
<td>10,404</td>
<td>4,912</td>
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<tr>
<td>SUMMER</td>
<td>10,767</td>
<td>3,312</td>
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<tr>
<td>FALL</td>
<td>9,490</td>
<td>3,833</td>
</tr>
<tr>
<td>WINTER</td>
<td>9,101</td>
<td>3,249</td>
</tr>
</tbody>
</table>

Not assuming intra-hour scheduling yet.

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Important Consideration when Estimating Operational Needs
Important considerations for estimating operational need to support variable generation resources

♦ Simple but use all available information
  • Uses simplifying assumptions to represent complex issues
  • Focus and care is placed on using all available information to best simulate reality
  • Runs quickly

♦ Transparent
  • Accepts user input assumptions
  • Uses fully transparent calculations

♦ Flexible
  • Can provide results across many scenarios and resource portfolios
  • User defines the analytical period and the system conditions
  • Can be updated as system and forecast capabilities change
Additional Reading

Chang, “High Wind and Solar Penetration on the Grid” NARUC Renewable Energy Retreat, Riverside, CA, October 7, 2010


2010 PacifiCorp’s Wind Integration Resource Study and Appendix, September 11, 2010


Katzenstein, “The Cost of Wind Power Variability,” presented to CEIC Advisory Committee, October 20, 2010
About *The Brattle Group*: Services and Contact

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- Mergers and Acquisitions
- Transmission

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Appendix
The Renewable Integration Model (RIM) uses statistical relationships of schedules and actuals to estimate services requirements.

Regulation requirement for each 5 minute interval is estimated with two components of variance of load and generation:

1. *5-minute forecast error*, PLUS
2. *intra-5-minute volatility*
RIM summarizes regulation, load-following and day-ahead commitment needs by season

- RIM uses the standard deviations to estimate the services needs
  - User can input the magnitude and the number of standard deviation used to determine the needs
- RIM takes into account the correlation between sites and forecast errors
  - All of which are parameterized and user-driven
- RIM reports the operational requirements for regulation, load following and day-ahead commitment for each season
Observations from Other Recent Integration Analyses

- Compared to production cost simulations, RIM’s variable cost estimation provides consistent results as other modeling techniques.
- Regulation and load following are translated into reserves that are “held aside”.
- When certain resources are on reserve, inefficiencies increase by requiring certain generators to be held “on reserve” or use out-of-merit dispatch.
- RIM simulate with using efficiency “penalty” between in-merit resource and the “next one up” on the dispatch ladder.
- This is consistent with system operations.
- All production efficiency assumptions can be adjusted based on empirical data.
Primary strengths of the RIM methodology

- Full transparency
- User control over key assumptions
- Ease of updating parameters as better information is available
- Ease of adaptation to forecast improvements
- Accommodates many VER categories
- Facilitates policy discussions