Resource Adequacy: How did we get here (and where are we going)?

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Outline

• Historical reliability assessments: LOLE
• Impact of renewables
• Emerging interest in portfolio effects
• What about transmission, and long-term weather?
• Gap between model capability and decision-making
Resource Adequacy
Resource Adequacy (RA) is a counting problem

• Have we built enough stuff to supply demand at some future date(s)?
  o RTO, utility IRP, region
• “How adequate” can be turned upside down into “How often do we have a problem?”
• How many problems?
• How long did they last?
• How large was the energy deficit?
• How large was the capacity deficit?
What should be counted?

• Do we want to count only resources (RA)?
• Do we want to include resources plus transmission (system adequacy)?
• Do we want to consider external support from power pool participation or other neighbors who might have the capacity/energy to help during an emergency?
...and what is “acceptable” RA target?

- How many loss-of-load events per period?
- How long of a LOL event is too long?
- How much demand/energy is “ok” to not supply?
- Policy questions

- Trade-off between reliability and cost. 
  *Reliability is not free*
Traditional Approach to RA

• Often measured based on installed capacity, peak load, and a planning reserve
• A fixed planning reserve margin (PRM), often in a range of 12-15% above forecasted peak demand, was (and is still, unfortunately) common
  o 10,000 MW peak, 11,500 Installed capacity is a 15% PRM.
• However, this isn’t a true reliability measure; the following questions are not answered:
  o How often does it fail?
  o How long are failures?
  o Or...how successful are we in keeping the lights on?
• And – it does not work with high levels of renewables
Resource Adequacy: From PRM to LOLP

- **How adequate is adequate enough?**
- Quantify the number of times system will be inadequate – often measured as hours/year or days/year (1d/10y ≈ 99.97%)
- Probability that demand will exceed supply: Loss of load probability (LOLP)

Forced outage rates source: NERC
The “Loss of load” part of this term should be changed to “probability of emergency import” in interconnected systems.

Forced outage rates source: NERC
First assessments using LOLP

- Computation capability limited
- Select the peak hour from each weekday
- Exclude holidays (~6) falling on weekdays
- 5 x 52 – 6 = 254 peak demand values used for an annual assessment (about 3% of the year)
LOLP development

• Calabrese et al introduced convolution method in 1947 that is still common
• Calabrese (1950): 1 day in 50 years “should be satisfactory”
• *Remember – one data point per non-holiday weekday!*
Terms

• Probability: between 0, 1 inclusively
• P(heads) = 0.5
• Expected value = probability x number of trials (or similar)
• Expected number of heads after 100 coin tosses = 100 x 0.5 = 50
• Power system
  o LOLP = loss of load probability (0.0-1.0)
  o LOLE = loss of load expectation (days/year, hours/year, etc.)
LOLE development: 1 day/10 years

- 1 day/10 years is a “nice round number” for a reliability target
- Is it from Marsh?
- **We don’t know where it came from**
- Corresponding LOLP = 1/3650 = 0.0002734

Remember, one data point per non-holiday weekday.
Renewables are complicating risk assessment

• **Traditional**
  o Most LOL risk during/near system peak
  o Focus on daily LOLP; ignore hourly data

• **With renewables**
  o Shifting risk periods
  o More interest in hourly view
  o More interest in energy metrics

• **Fortunately, methods and computational tools exist that can help**

See ESIG: Redefining Resource Adequacy:
Effective load-carrying capability (ELCC)

- Rooted in base-load evaluations from the 1950’s forward
- Easily adapted to renewables
- Part of a framework of reliability assessments

- ELCC calculation assumes no other changes to power system
Graphical depiction of ELCC

Each generator added to the system helps increase the load that can be supplied at all reliability levels.

Added generators

G_i  G_{i+1}  G_{i+2}  G_{n-2}
Recipe for ELCC

• Reliability model, or production simulation model

• Inputs:
  o Hourly demand, wind, solar, hydro data
  o Resource data including forced outage rates
  o Multiple years of time-sync’d data

• Output
  o Each model run provides LOLE output
  o Iteratively re-run model until LOLE target is achieved with, and without, renewable resource (multiple model runs)
Enter: Renewables (wind example)
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Partial capacity contribution

Steeper ramps

Lower turn-down

MW

Load

Net Load

Wind
Example Wind/Solar Capacity Value

Wind/Solar Capacity Value Depends on...

- Penetration rates of
  - Wind
  - Solar
- Storage and mode of operation
- Maintenance schedules
- Demand patterns/levels
- Forced outage rates of other units
- Imports/exports
- Hydro generation patterns
- Inter-annual variation

Andrew Mills, LBNL
Storage and demand response examples

Emerging interest in portfolio effects

Emerging interest in portfolio effects

Emerging interest in portfolio effects

Wind and Storage Example

How does weather affect RE?

Figure 10. Optimal distribution of wind capacity using 1996 data

Figure 11. Optimal distribution of wind capacity using 1997 data


California RPS Integration Study

Minnesota Wind Integration Study
What is appropriate reliability/RA target?

• 1 day/10 years legacy target, no real justification, focuses on daily event
  o No information about the event length, depth, capacity

• Are 10 “small” events the same as 1 “large” event?

• Should we focus on hours lost, capacity lost, energy lost?
Transmission can increase reliability, enhance markets, and reduce need to build resources
Transmission can play a critical role

- Increasing transmission links and associated operational coordination can reduce the need for installed capacity

Adapted from Eastern Wind Integration and Transmission Study https://www.nrel.gov/docs/fy11osti/47078.pdf

What do we need to do?
What do we need to do?

• Integrate resource, transmission, distribution planning
• Focus on “energy-first” planning
• Think more about long-term weather impacts — on demand and resources (wind, solar, hydro)
• Re-think metrics
• Incorporate DR, storage
• Close the gap between technical modeling capability and decision-making
Integrate transmission & resource planning

Example: MISO/NREL Study Process (EWITS, 2010)

1. Analyze NREL Mesoscale Data
2. Define Wind Generation Scenarios
3. Generation Forecast and Generation Location
4. Production Simulations ("copper sheet" and constrained)
5. Transmission Overlay Development
6. Develop Wind and Load Profile Data
7. Statistical Analysis
8. LOLE/ELCC Analysis
9. Wind Integration Analysis
10. Synthesis/Reporting

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Integrate G, T, D planning (HI example)

HECO Integrated Grid Planning

- Incorporate market input
- Utility solutions vs aggregated DER vs tariffs
- Integrated T&D solutions

Transmission planning challenges

- Most are well-known...
- Design and build for the short-term, or the long-term?
- Renewable energy siting in advance?
  - Example: ERCOT’s Competitive Renewable Energy Zones (CREZ)

Energy-first planning

• Who is in charge?
• "energy-first"* planning
  o Focus on clean energy first
  o Then “fill in” to achieve RA (energy adequacy?)
• Fill in with
  o Storage
  o DR/dispatchable demand
  o Quick-start thermal
  o Other
• Move away from “peak only” and focus on energy adequacy

*First coined by Dave Olsen, CAISO
Weather, weather, weather

It’s the meteorology stupid!

Extreme Events
- Impacts
- Scale
- Longevity
- Connections

Uncertainty
- Climate scales
- Weather scales

Resource Diversity
- In time
- In space

Transmission Planning

Correlations:
- Wind ↔ Solar ↔ Load ↔ Hydro

Forecastability

Variability
- Seasonal
- Diurnal
- Ramping

Climate Change

AMS Washington Forum - Renewable Energy Session
April 28, 2021

Justin Sharp

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Long-term weather; need more robust planning

• As a species, humans often don’t have the capability to incorporate uncertainty and volatility into planning

• Planning is usually done based on “average” or “representative” weather

You’re so above average!
Long-term weather; need more robust planning

• As a species, humans often don’t have the capability to incorporate uncertainty and volatility into planning

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You’re so above average!

That’s cold!
We need more work on metric comparison

Example Comparison of LOLH and EUE

Two LOL events
LOLH = 6 hours
EUE = 84.2 GWh

Avg LOLH/event = 3 hours
Avg EUE/event = 42.1 GWh

LOLH = loss of load hours (hours of emergency import), number of hours of shortage
EUE = expected unserved energy (emergency import energy)
### Some potentially useful metrics

Break down the wall between modeling capabilities and policy-making – and **re-work target reliability**

#### Models (generally):
- LOLH – counts hours with LOL events
- LOLE – loss of load expectation (i.e. expected value). Can be measured in days, hours, or ...
- LOLEv – counts events
- LOLH/LOLEv – average length of LOL events
- EUE – expected unserved energy (MWh, GWh)
- EUE/LOLEv – average energy lost in LOL event

#### Policy (generally):
- Planning reserve margin (% by which installed capacity exceeds peak demand)
- 0.1 d/year (sometimes)
- Single year of modeling
Example demand response for regulation

http://enbala.com/solutions.html
Animation
Close the gap between modeling and decision-making

Models

Multiple potential metrics that models can produce today.

Decision-makers

PRM or 1d/10y – often not even calculated properly.
Conclude

- We already have much of what we need...in our collective heads/models, but not in practice
- Best practices must evolve – and we need to re-think reliability targets
- Need *common framework* for all resources
- We need to focus more on inter-annual variability inherent in wind/solar/hydro and demand
- We need to pay more attention to dispatchable demand and storage, and continually improve on algorithms
- Integrate transmission and resource planning
- Connect the tracks!
Questions?
Appendix: Long-term adequacy and resilience
Our planning processes are not robust

- As a species, humans don’t have the capability to incorporate uncertainty and volatility into planning
- Planning is usually done based on “average” or “representative” weather
Single-mode failure and resilience

• Less convolution; more Monte Carlo*
• Get the fundamental probability distributions correct (a hard problem)
• Summer vs. winter forced outage rates should be a dependent variable, not an independent variable
• Lack of fuel supply for multiple gas plants
• Create plausible load-weather-RE years (NREL’s forthcoming study on extreme weather)
• Explore the corners

* Convolution example: 100 coin tosses. P(head) = 0.5. Expected heads = 50. Monte Carlo: Computer “tosses” the coin 100 times. Actual number of heads will be “close” to 50. Also results in 100 “scenarios” of coin toss
Infrequent events

- What is the risk of
  - “major” heat storm every 20 years
  - “major” polar vortex every 13 years
- And how do collect good data sets and assess resilience?

- How to account for impact of climate change on these variables?
Multiple dimensions

MW dropped

Large and short

Large and Long

EUE

Small and Short

Small and Long

Time
Issues in assessment

• See NREL’s forthcoming report on extreme weather
• Is event outside “normal” data sets?
• How to define large-scale threats; i.e. what happens and where? What damage/outages?
  - Use extreme weather scenarios as inputs
  - NERC/National Labs archive for power sector use
• Each region will have different risk profile, for example:
  - SERC: hurricanes
  - SPP/MISO: tornados
  - ISO-NE/MISO: cold weather, gas supply disruption
  - CAISO: forest fires
• Normalize reliability score to scale 0-10 based on metric of choice (LOLH, EUE, ??). 10= resilient, 0=failure
Example Resilience Diagram

Scoring: 10=reliability target met; 0 = severe outages
Resilience to different storm profiles

Resilience to Different Extreme Storm Profiles

Scoring: 10=reliability target met; 0 = severe outages