Future of Flexibility from all Resources

Surprising things for system operations and markets

Mark Ahlstrom, ESIG and NextEra Energy Resources

ENERGY SYSTEMS INTEGRATION GROUP

Elegance and Innovation

Innovation

- Skipping ahead to what will be… or should be

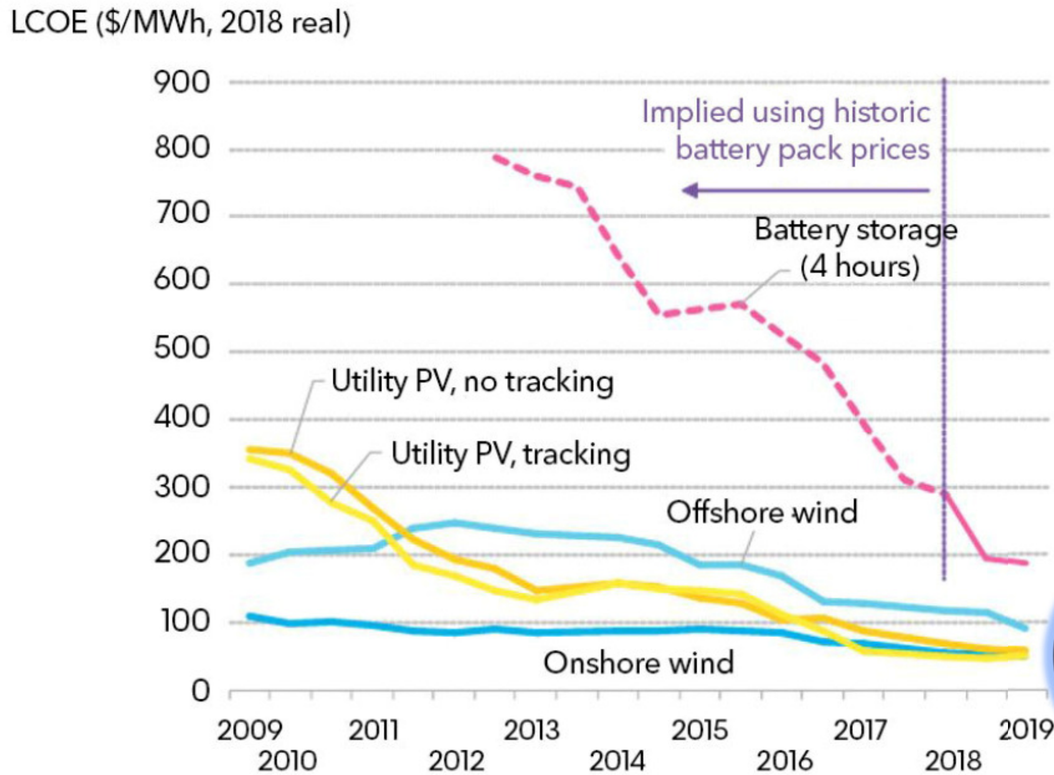
Our goal

- Advanced thought and sophistication in an elegant implementation

Elegance

- Non-obvious, sophisticated simplicity
- Elegance of a conceptual or design nature, and best when both
- Once others understand it, they consider it to be obvious

Global benchmarks - PV, wind and batteries



Source: BloombergNEF. Note: The global benchmark is a country weighed-average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system running at a daily cycle and includes charging costs assumed to be 60% of whole sale base power price in each country.

Our digital revolution – disruptive change

Non-synchronous resources are electronically coupled to the grid

- This is a digital revolution in power generation, with the ability to program the behaviors that we desire, but the need to understand exactly what we want

Storage – What is it?

- We are used to generators and loads, but storage is both and neither
- Does a bit of storage enhance everything? Separate or embedded? Everywhere?

Storage Hybrids – Even more disruptive?

- Hybrid “storage + solar” power plants… or “storage + anything” power plants
- Virtual power plants (VPPs) – including aggregated distributed energy resources (DERs)

Given enough of three key ingredients
(energy, electronics, software)…

we can emulate any “machine” that we want or need
(real or imagined).

If we can can make what we want, then why not make “more ideal” resources?

What might a more ideal resource be?

- No startup time, no minimum run time, no minimum down time, etc.
- Ramps quickly and on command across its entire power range
- Linear operational characteristics without discontinuities/non-convexities

How can we make them?

- Current resources plus storage services could become ideal resources (physically or virtually)
- Grid-forming inverters to standardize electrical properties, even with diverse technologies
- Examples:
  - PV + Battery + Gas Hybrid Power Plants
  - Aggregated DERs or Distribution System Operators

Hybrid resources – complete game changers

Renewable hybrids are getting surprisingly affordable

- Leads to dramatic internal design changes and higher effective renewable capacity factors
- Oversizing generation, using “planned” self-curtailment, efficiency/optimization/analytics

Hybrids dramatically increase the value of better forecasts

- High quality forecasts of renewable generation and energy prices are critical to the hybrid plant’s operating and bidding strategy (better forecasts are directly monetized)

Hybrids may change market products, market design and market participation

- Offer prices are based on the hybrid’s perception of future opportunity cost
- Conventional assumptions of offers based on marginal fuel cost are no longer relevant
- System operator will not know (nor nor should they know) the hybrid's internally optimal performance strategy, and this strategy will vary based on forecasts and risk tolerances

Hybrids can provide the “Grid Services” that system operators really want

Grid Services

Concepts

- In the long run, can we allow markets and system operators to focus on the services that they really want rather than technology-specific “snowflakes” they are offered?
- How would we define these desired, high-level services from scratch today?
- Can we directly align services with the “prime directive” of the system operator?
  - *Maintain a balanced, reliable system across planned and unplanned conditions in an economic way*

Implications

- The real time operator in the control room (and therefore, the market software and energy management software) wants to know that they have sufficient *energy, flexibility and contingency reserves* available to maintain a desired level of reliability at all times and places
- Expecting the system operator (or the market) to be responsible for technology-specific quirks could become a historical artifact when sufficient future resources (both conventional and renewable) can directly provide Grid Services at low cost

Once we have the *capability* to make an ideal resource,
does it become an *obligation* to perform like one to participate?

No, the market can still construct what it needs from non-ideal parts,
but don't waste time and effort on what is going away.

But should we use Grid Services as the basis for assigning value?

Yes, because if a hybrid can construct the Grid Service cheaper
than the market can, then we should allow it to do so.
Seek elegance, not complexity.

This makes probabilistic forecasting and operations more valuable to more participants, and done right, should result in better prices, better performance, and better results for customers.

If we're expecting disruption from storage, exponential growth in market participants, and innovation at the digital pace, then what do we do?

Current top-down approach to operations and markets

Allowing participation (via parameters/data structures) →

Universal Participation Model
- Still a top-down approach
- Complicated to "get it right"
- Computational complexity

Smarter Agents

Transitional mapping by system operator, or market participants?

Ideal Resources
- Hybrids
- Virtual Power Plants
- Aggregated DERs

System operator must support ideal resources eventually, and should want to because they directly provide the Grid Services that are really needed, so should this become the standard model?

Top-down optimization – a long-run losing battle

Over time, the "more ideal" resources will become increasingly attractive

- Ability to innovate and optimize behind the fence as a single resource (virtual/physical)
- Optimized for cost and performance, they will eventually dominate market products
- Innovation will include hybrids with both renewable and conventional resources

The system operator will no longer have (nor should they need to have) the information needed for top-down optimization approaches

- Simple storage (e.g., Order 841) is difficult enough, but hybrids, aggregated DERs and virtual power plants will break the top-down paradigm; Why is this so?
  - No way for system operator to know the true marginal cost, replacement energy cost or lost opportunity cost of the resource (because it depends on internal strategy and optimization)
  - Markets can still work, based on offers of Grid Services from the resources, but cannot assume to calculate the marginal cost or opportunity cost of the market participants

The Regulatory Debate About Energy Storage Systems

(IEEE Power & Energy Magazine; Sep/Oct 2017; Enés Usera, Pablo Rodilla, Scott Burger, Ignacio Herrero, Carlos Battle)

Guiding principles from this paper:

- Technology-specific restrictions and products should be avoided where possible
- Only technical requirements based on actual physical limitations of the system should be preserved
- Energy and flexibility:
  - Bring market-clearing closer to real time to allow agents to exhaust their ability to correct their forecasting errors and variability—an area where energy storage resource could excel
  - Short-term flexibility market products through technology-neutral market products that respond to actual system needs
  - Long-term frequency reserve markets as call options to facilitate storage/VER participation
- Capacity: Products that more closely reflect system operations and flexibility needs

Are we looking at flexibility (and capacity) wrong?

- Isn't flexibility more than just ramping energy?
  - How to create flexibility products that don't suppress scarcity pricing?
  - If flex is priced at energy opportunity cost, and energy goes to zero, then is flex worthless?
- If system balancing is the real objective, is flexibility the real product?
  - Is flexibility really optionality (more than just ramping of energy)?
  - What is the benefit of deferring decisions until the last reasonable moment (as in ERCOT)?
- How does the concept of capacity change in a future with much more flexibility on both the load and generation side?
  - Larger populations of intelligent agents that are flexible, sophisticated and automated

Finally, a word on nomenclature

NERC, FERC and others have largely standardized the nomenclature

- Variable Energy Resource (VER)
  - A resource using a variable fuel source (e.g., Pmax will vary with the weather)
    - Wind, solar, run-of-river hydro (although temp/dewpoint impacts many conventional resources)
- Non-synchronous Resource or Inverter-based Resource
  - A resource that is electronically (rather than electromechanically) coupled to the grid
    - PV solar, battery storage, wind, HVDC, other resources and loads using inverters/converters

"Intermittent" is better applied to conventional contingency events

- *"Alternately functioning and not functioning or alternately functioning properly and improperly."*
  - Example: trip of a large conventional plant, which we cover with reserves & socialize the cost
- Variability and uncertainty of VERs is much slower and more predictable

Mark Ahlstrom
President, Energy Systems Integration Group
VP, Renewable Energy Policy, NextEra Energy Resources
mark.ahlstrom@nexteraanalytics.com
Twitter/LinkedIn @markahlstrom

www.esig.energy

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