Possible Pathways Towards 100% RE

How might we get there? Are there guiding principles? Are we overly constrained by our historical context? What might disruptive change look like?

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Pathways – Incremental change

We have what we need for the next few years (with good engineering)

- We can probably push existing technology up to 60-80% of annual energy

We have choices

- Do we replace synchronous inertia or embrace low-inertia operations?
- Do we replace short circuit current or embrace other protection methods?
- Do we change how we use frequency, capacity and reserves?
- How do we balance efforts for 100% clean electricity with electrification and broader energy systems integration goals that span all energy vectors?

Multiple Pathways – To a similar endpoint?

Taking the first example of inertia…

- Various systems or regions may take different pathways
  - Minimum commitment of synchronous units as grid-forming (GFM) inverters deploy
  - Deploy synchronous condensers as GFM inverters deploy
  - Full non-synchronous operation, even adding GFM inverters to conventional resource
- All could end up at a similar destination of nominal 100% operation

Broader strategic choices are important

- The big picture matters, so don't underestimate the value (and challenges) of understanding strategic alternatives, transition planning and scenario analysis

Challenges create opportunities

Lower energy value may challenge markets, but may create benefits

- Headroom (and curtailment) becomes an opportunity to do other things
- Spilling clean energy is only a problem if it economically interferes with the ability to otherwise reduce some other cost (such as emissions) or satisfy contractual obligations

Examples where our current thinking may be missing something

- Today, market design thinking and market revenues are dominated by energy
- We keep talking about the increasing value of flexibility, but do current ramping products really encourage flexibility, or are they still an example of “energy-based” thinking?
- Is our thinking about reserves and capacity similarly rooted in old ways of thinking?

Disruptive versus Incremental Change

First IBM PC – 1981

First Honeywell Laser Ring Gyroscope – 1982

First iPod – 2001

First iPhone – 2007

We overestimate what we can do in a year and underestimate what we can do in a decade.

Yes, we will have incremental, predictable change in all that we do today.
But we will also have disruptive change that creates things that are very, very different.

It will be difficult to predict, which is why it is so disruptive,
but we now have many examples of digital disruption.

Our digital revolution – Disruptive change

Non-synchronous resources are <u>electronically</u> 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 – 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)

Why hybrid resources change the game

Hybrids leads to dramatic internal design changes “behind the meter”

- Oversizing generation, using “planned” self-curtailment, efficiency/optimization/analytics

Hybrids don’t fit into the system operators conventional rules/mission

- Can be physical or virtual, but if components are required to be separate market resources, market rules prevent realizing the range of integrated values (fast, coordinated, optimized)
- System operator could theoretically provide this service (bilateral virtual hybridizing services), but this detracts from their mission; provide the platform and facilitate third party services
- System operator does not (nor will they) have access to the hybrid's detail of their internally optimal performance strategy

Therefore, system operator should support and encourage hybrids (physical, and virtual via outside-of-market services), and to the extent possible, should move in the direction of making all resources become more ideal sources of the higher-level Grid Services that they truly want for their mission.

Grid Services

The concept

- In the longer run, can we allow markets and system operations to focus on the services that they really want rather than technology-specific variants that they are offered?
- How would they define these desired, high-level services from scratch today?
- Can we align services with the objectives of the system operator – maintaining a balanced and reliable system across planned and unplanned conditions in an economic manner?

Questions to start pondering

- Are there practical ways for resources to provide desired higher-level Grid Services rather than offer their “naked” hardware characteristics (forcing the market/system operator to deal with technology-specific detail)?
  - Remember, we can emulate any real or imagined “machine” that we want or need
  - We can create hybrid resources (physically at one site, or virtually via third-party services)
- Can we dramatically simplify market design and improve system operations by doing so?

We can make ideal resources

What is an ideal resource? (Hint: it's not just a gas turbine, like in early integration studies)

- Starts instantly, Pmin=0, ramps quickly and on command from 0 to Pmax
- No startup time, no minimum run time, no minimum down time, etc.
- 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 could maintain equivalent electrical properties for hybrid projects that include diverse technologies
- Plant controllers could coordinate diverse components as a single resource
- Examples:
  - Gas + PV + Battery Hybrid Power Plant
  - Aggregated DERs or DSOs

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

Or at least use Grid Services as the basis for assigning value?

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
- VPPs
- Hybrids
- Aggregated DERs

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

Top-down optimization – a long-run losing battle

Over time, VPP "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 hybrid resources that include 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

One scenario: What might disruption look like?

We will have both synchronous and non-synchronous BPS elements, but most resources will be hybrid resources that approximate our vision of an ideal resource

One example: hybrid of a gas CC, PV solar and battery energy system

- GFM inverter for PV/battery side makes electrical properties virtually identical whether currently running the synchronous gas side or the PV/battery side (or both) via same POI
- Appears as a single ideal resource to the market and the system operator, capable of starting instantly and ramping continuously from zero to Pmax
- Offers high-level Grid Services in the four-hour and real time markets

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

- 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 forecasting errors and renewable energy 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: Design products that more closely reflect system operations and flexibility requirements

Who can own and operate storage?

- Network businesses contract for services from third-party energy storage system operators
  - Remove debate about ownership, cost-based and market-based service provision, etc.

And finally, please remember…

Communication is critical

- Use consistent and accepted nomenclature
  - Variable (not intermittent), NERC/FERC terms (VER, DER, non-synchronous and synchronous)
- Use progressive tone and language
  - We're here to solve challenges, so this is an exciting "can do" time
- Avoid falling victim to the "out of context" headline in the press

Bring the industry along from the start

- To be effective, enhancements need to get into production and deployed at scale
- Bring others along by participating at places like ESIG, IEEE, EPRI, NERC, CIGRE, etc.
- Explain transmission/distribution technical differences without enflaming other sensitivities
- Pathways matter – how do we get from "here" to "there" in our huge interconnected system?

This is critically important work, and it's our future, so be careful with it!

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