Hybrid Resources as Power Plants

Role and Value of Hybrid Resources in the Energy Mix

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ESIG

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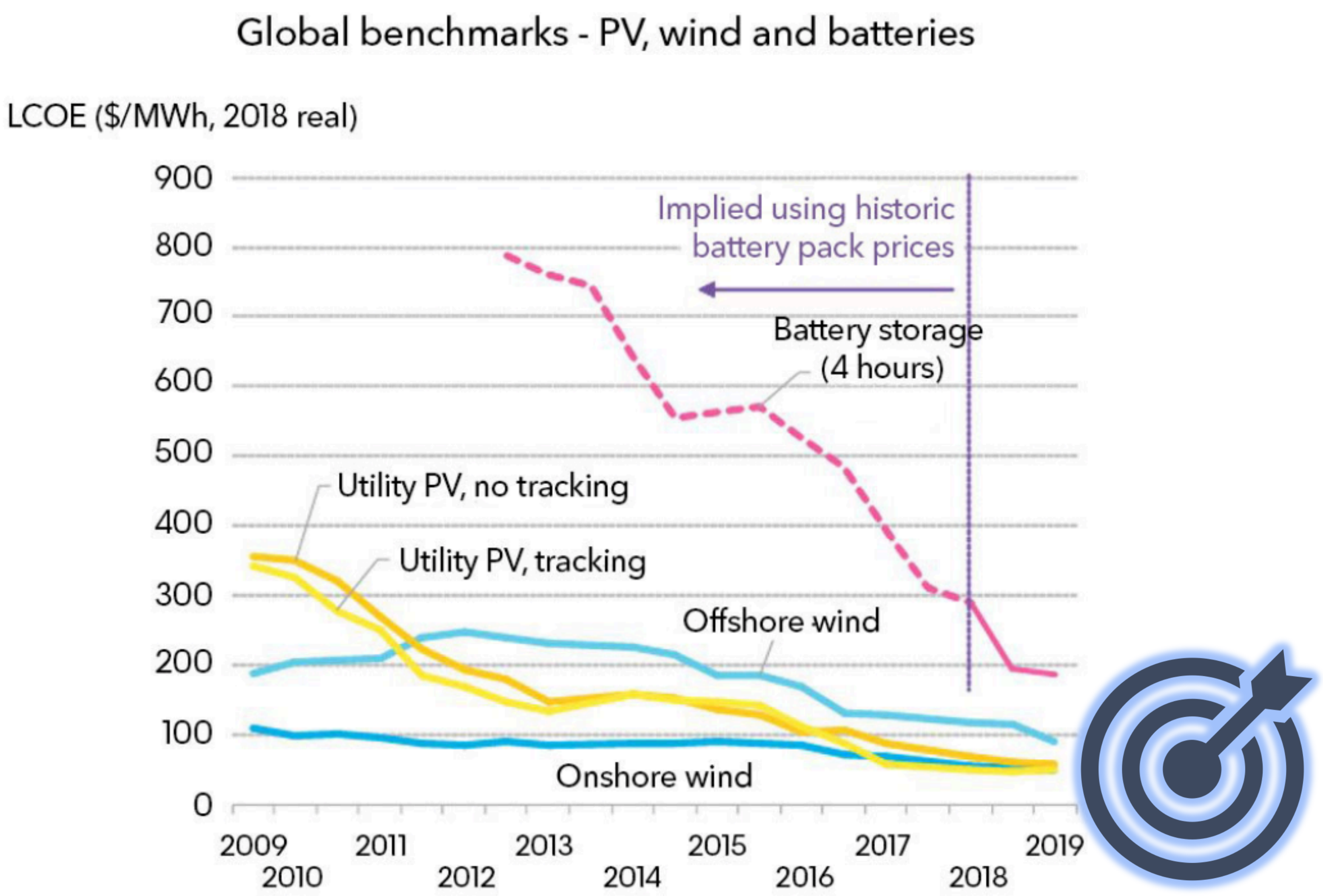


Source: BloombergNEF. Note: The global benchmark is a country weighed-average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system running at a daily cycle and includes charging costs assumed to be 60% of whole sale base power price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

Software – Optimization versus Emulation

Power systems have traditionally emphasized optimization & automation

- Building a reliable system from a collection of relatively simple, less reliable parts
- Top-down optimization implicit in energy management, markets and models
  - I'll tell you when to start up and what to do… help optimize your return on your investment
  - You'll give me visibility and control so that I can build the services that I need from your parts

Software emulation is actually more common in the rest of our world

- Using software to make the higher-level interface for the "machine"
- The services at the interface are what matters
- Details of implementation (hardware or software) are irrelevant to user/customer

Hybrid Resources – Definition

A combination of multiple technologies that are physically and electronically controlled by the Hybrid Owner/Operator behind the point of interconnection (“POI”) and offered to the grid as a *single resource* at that POI

If treated as multiple resources, it is “co-located” rather than “hybrid”

The “aggregated resources” family of software-based resources:

• Co-located Resource	treated as multiple “known” resources sharing a POI
• Hybrid Resource	treated as a single resource offering services at the POI
• Aggregated DER	a hybrid resource using a population of DERs
• Virtual Power Plant	general term for all the valuable variants that come next…

A “True” Hybrid Resources Concept

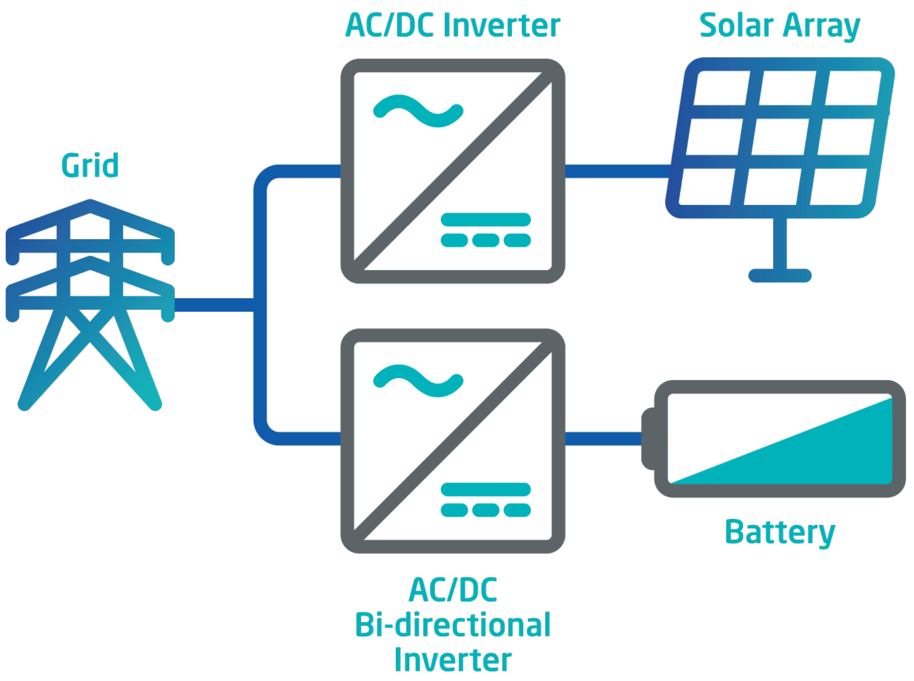
Uses an “intelligent agent” approach that internalizes the characteristics of the components behind the POI and offers energy and services at the POI like a conventional resource, but with more flexibility and fewer constraints through coordinated use of energy, storage, power electronics and software technologies

Or said more simply…

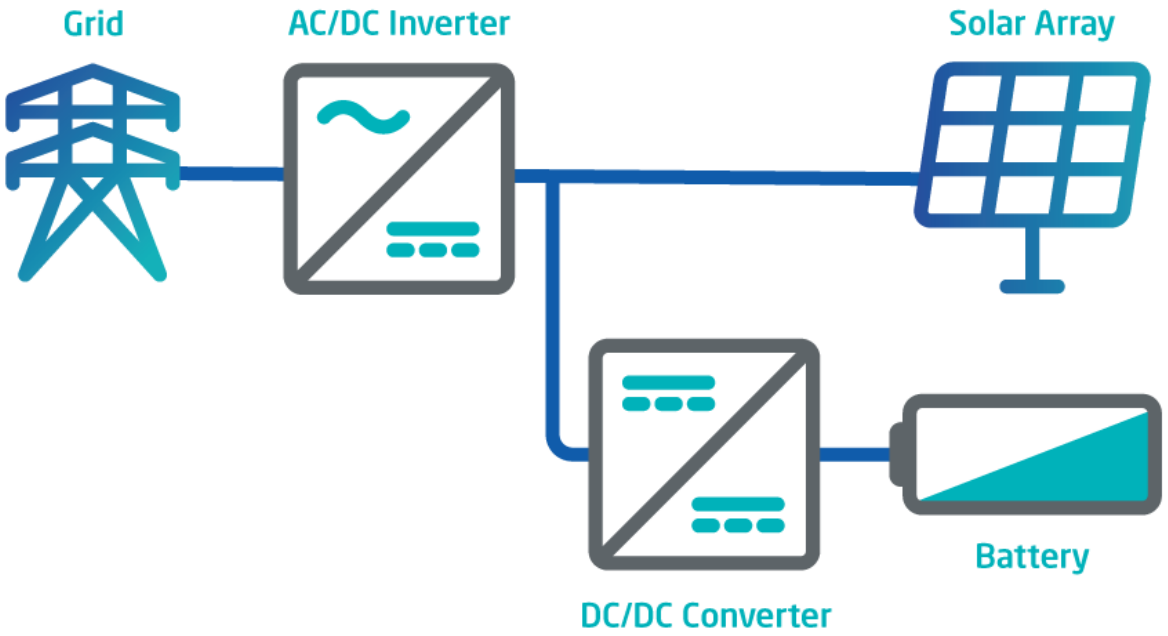
With sufficient energy, storage, electronics and software,
we can emulate any kind of electrical machine that we want or need

AC Coupled versus DC Coupled – Solar PV + Storage Example

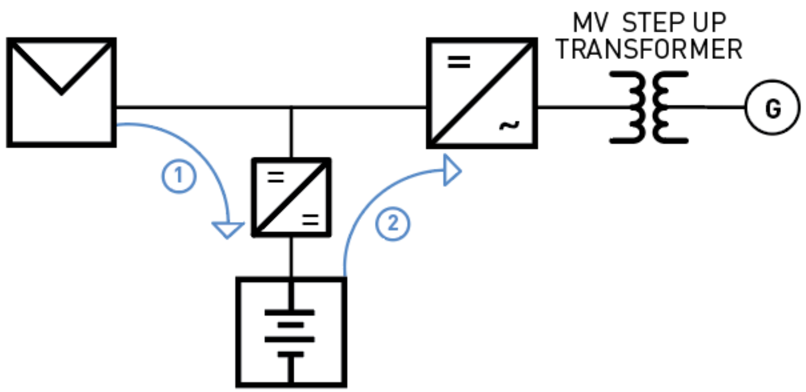
AC Coupled (Hybrid or Co-Located Resource)

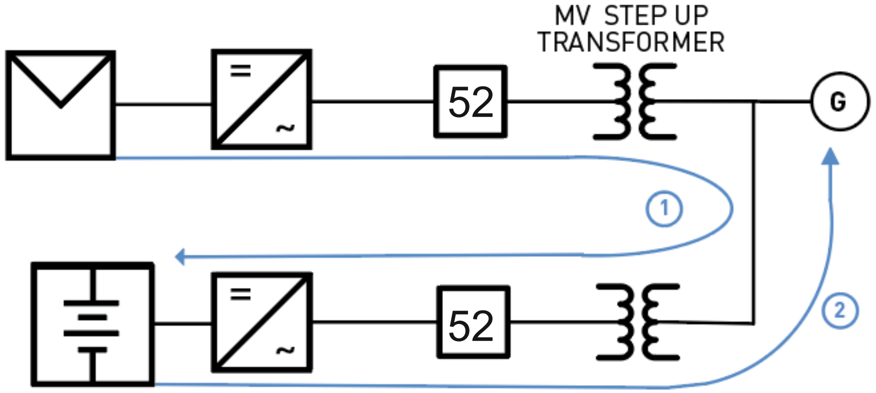


DC Coupled (Hybrid or Co-Located Resource)



HIGHER EFFICIENCY





DC-COUPLED

- 3 power electronic conversions
- 1 battery charge and discharge
- 1 transformer conversion

Efficiency = 89.2%

= .95 * .982 * .982 * .984 * .99

AC-COUPLED

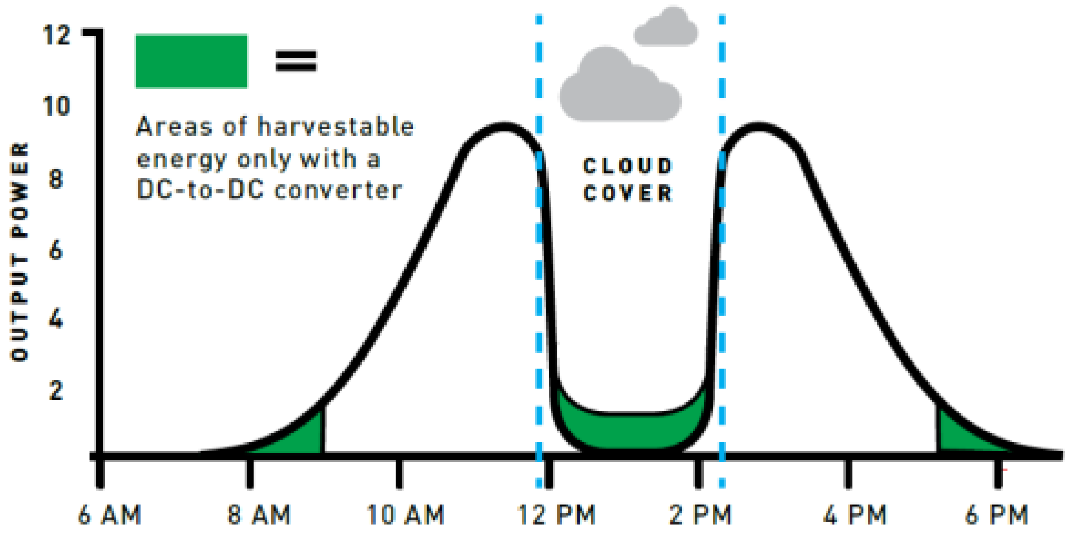
- 3 power electronic conversions
- 1 battery charge and discharge
- 3 transformer conversions

Efficiency = 86.2%

= .95 * .984 * .99 * .99 * .984 * .984 * .99

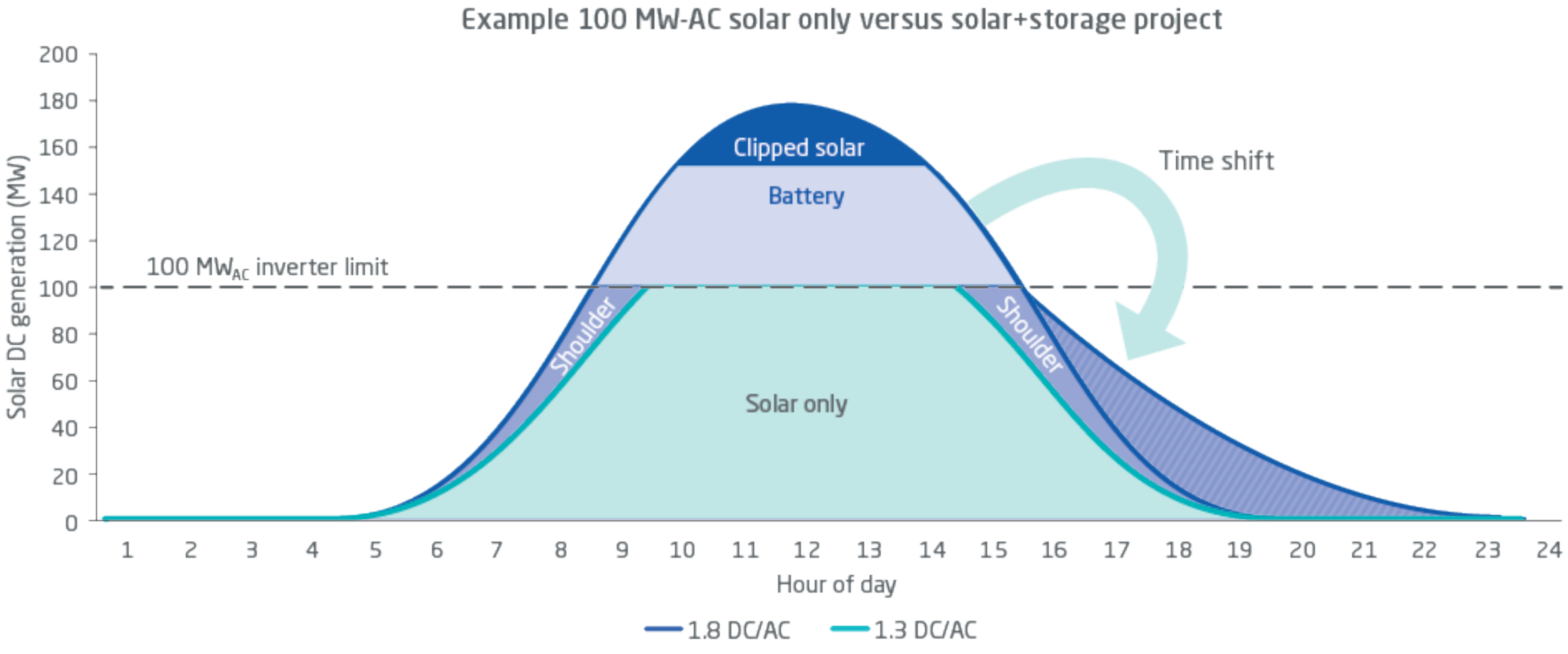
Assumed efficiencies: PV inverter = 98.4%, Battery inverter = 97.5%, DC-DC = 98.2%, transformer = 99%, batteries = 95% round trip

LOW VOLTAGE HARVEST (LVH)
ONLY WITH DC-COUPLED

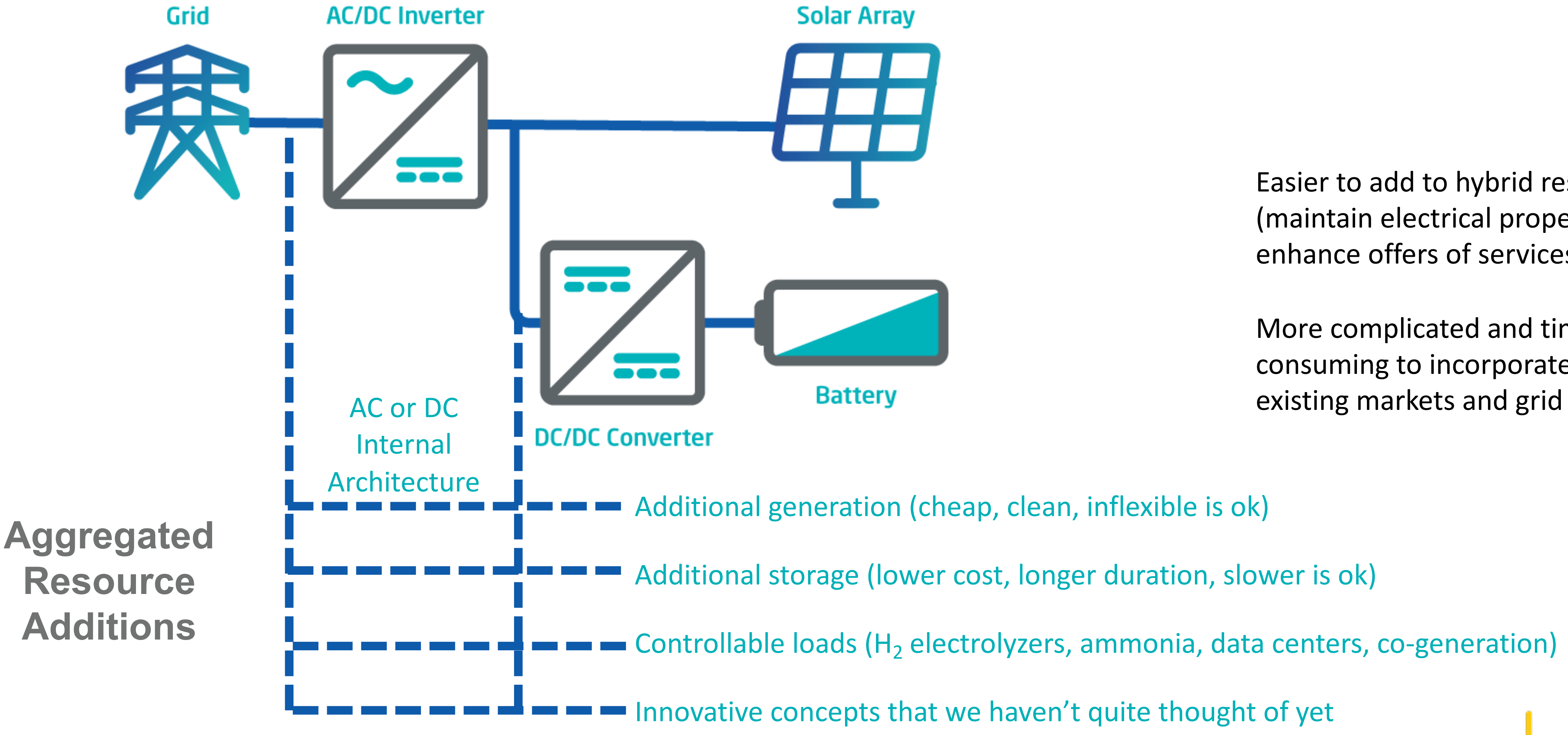


PV inverters harvest DC input when the array or string voltage is above a certain threshold. *This impacts generation at beginning of day, end of day and in heavy cloud cover.*

Maximizing solar with DC-coupled energy storage



Trends that are much closer than you think…



Easier to add to hybrid resources (maintain electrical properties, enhance offers of services)

More complicated and time-consuming to incorporate into existing markets and grid systems

Innovation & Complexity – Who is Responsible?

Modern resources are much more capable, more complex & sophisticated

- Battery storage – FERC Order 841 added many new market participation model parameters
- Hybrid resources and Order 2222’s aggregated DERS will add many more, and what’s next??

Highly parameterized “universal participation model” is one approach

- Retains centralized optimization, but with explosion of parameters and interdependencies
- Is it conceptually and computationally possible to keep ahead of the pace of innovation?

Higher-level grid services are the other “universal participation model”

- Focus on offers of technology-agnostic, high-level grid services at the POI
- Resources responsible for their offers and performance, pay/penalize based on performance
- Market’s priority is on valuing the services, particularly real time scarcity pricing

Benefits of Hybrid Resources

Can emulate an existing resource model, but with more flexibility and control

- A renewable plant that can provide not just "as available" energy, but also other services without needing to retain headroom (i.e., self-curtailing energy) to do it
- Like a gas plant that can start instantly and ramp down to zero

Directly managing batteries is complicated – hybrids simplify things for the customer

- The Hybrid Owner/Operator manages battery state-of-charge (through their offers of services) and optimizes the operation of all the components in the hybrid
- The system operator or customer sees a simpler interface that more directly matches their needs

In markets, provides a simpler and "more ideal" offer to the market operator

- The storage component of the hybrid can be charged from the renewable/generator component or from the grid—and that's an economic choice
- Provides fully convex, one-part offers* without advance commitment requirements, startup costs, minimum generation levels or other constraints

* Monotonically increasing energy offers without startup or no-load fees. For a good explanation of convexity and offers, see: https://www.iso-ne.com/static-assets/documents/2015/06/price_information_technical_session11.pdf

Motivates Beneficial Behavior

Hybrids are motivated to use the best forecasting and optimization methods

- Example: probabilistic PV forecasts backed by storage to firm variability and uncertainty

Hybrids are motivated to use sophisticated analytics, controls and innovation

- Deeply understanding battery degradation performance, opportunity costs and risks
- Optimizing the power plant design to maximize the services that are most useful and valued, while minimizing the risk of delivering such services
- Constantly working to improve, innovate and be better at providing value

Market design should allow for future adaptations – encourage innovation!

Summary – Closing Thoughts

1) Given sufficient electronics, software, energy and storage, we can create any kind of electrical machine that we want to see at the point of interconnection (POI)
2) To simplify initial use, hybrids can offer energy and services at the POI like a conventional resource, but with more flexibility and fewer constraints
3) For reliability and modeling, system operators must know electrical characteristics at the high side of the POI (including for disturbances and state estimation)
4) For adequacy/planning/operations, any resources that offers to provide a service (whether via capacity payment, contract or cleared offers of market services) should provide real-time performance at least as good as conventional expectations
5) As long as #3 and #4 are maintained or improved, other changes behind the POI (adding more batteries, generation, loads, etc.) should not be material changes
6) Markets should get simpler, support innovation, and focus on the value of accurate real time price signals, single-part offers, and pay for performance

ESIG – Task Forces & Topics related to Hybrid Resource

1) Revisiting Resource Adequacy
   - Necessary changes to the concepts of capacity value and resource adequacy
   - A planner may prefer a co-located resource, but an operator will come to prefer a hybrid resource
   - Pay for performance, encourage innovation and upgrades, identify the services that you really want
2) Plasticity of hybrid resources as a hedge against stranded assets
3) Populations of intelligent agents – reliability and resilience benefits
   - Reliability is fundamentally dependent on maintaining system balance in real time
   - Importance of accurate real time price signals for long-term procurement/hedging, innovation/enhancement, offers of services and population response
4) Many other topics
   - Macro grid transmission, grid-forming inverters, operating at very high non-synchronous penetrations, global examples of aggregated DERs and DERMS/DSO concepts, best practices for system operators undergoing grid transformation (core member of the Global Power System Transformation Consortium)

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