Dispatching Long Duration Storage on High PV Systems

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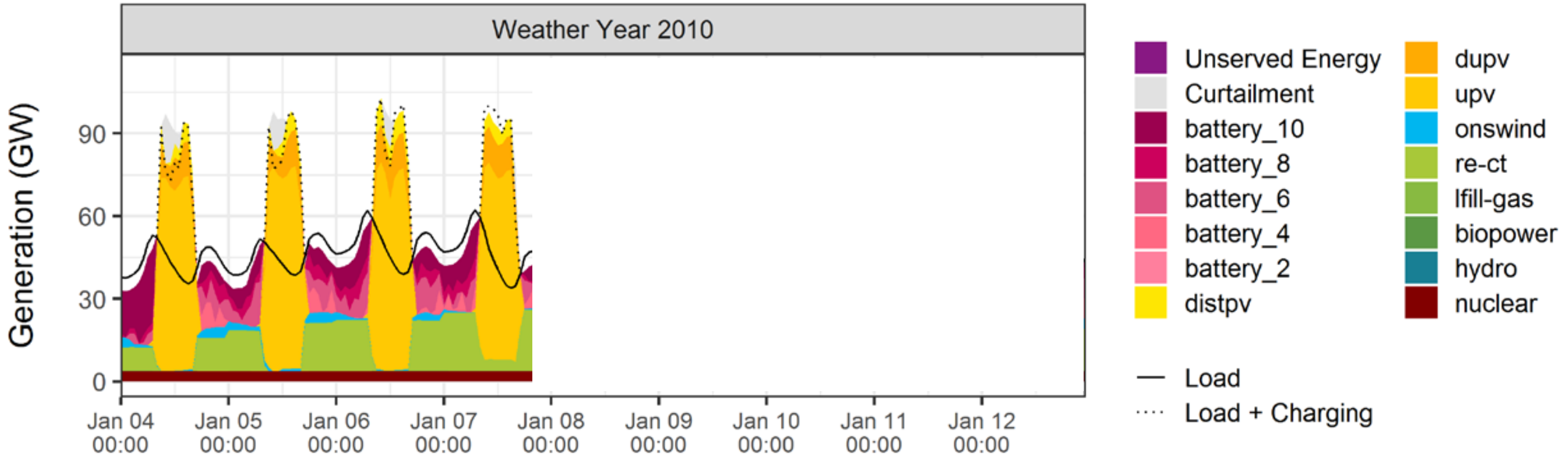
2022 Meteorology and Market Design for Grid Services Workshop

June 7, 2022

Long duration storage optimization requires looking further ahead than typical markets today

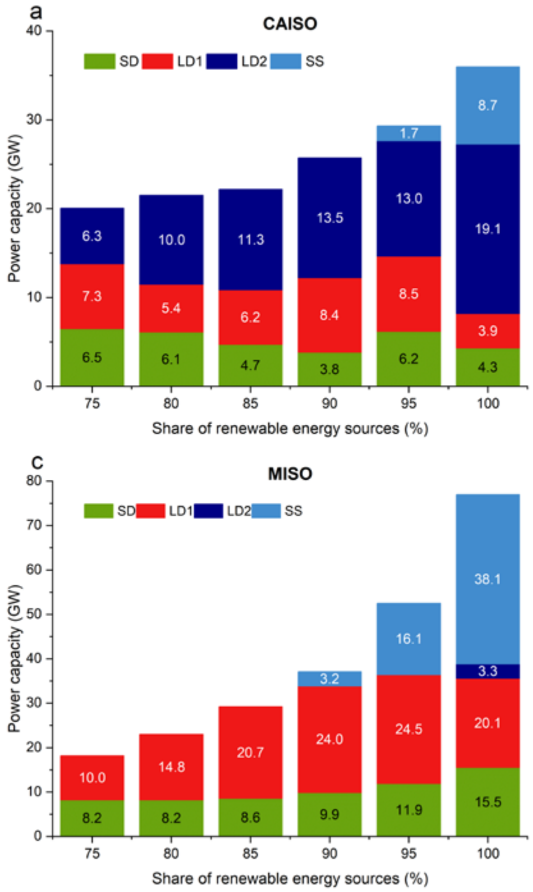
- Typical markets today include a day-ahead commitment phase and a real-time dispatch phase. This allows storage operators to identify value 1-2 days in advance
- However, in high variable renewable systems, seeing farther ahead can be advantageous for long duration storage (8-24 hours)



When does this matter?

Research done by members of our team indicates that long duration storage becomes important for achieving renewable shares > 50% and is critical to systems studied with >75% of carbon-free energy, a threshold well below what several states and utilities have goals to achieve.

- Denholm, Paul, Wesley Cole, A. Will Frazier, Kara Podkaminer, and Nate Blair. 2021. The Four Phases of Storage Deployment: A Framework for the Expanding Role of Storage in the U.S. Power System. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77480.
- Guerra, Omar J., Joshua Eichman, and Paul Denholm. 2021. "Optimal Energy Storage Portfolio for High and Ultrahigh Carbon-Free and Renewable Power Systems." *Energy & Environmental Science* 14 (10): 5132–46. https://doi.org/10.1039/D1EE01835C



SD: Short-duration storage (based on Li-Ion battery), LD1 and LD2: Long duration technology 1 (based on compressed air energy storage) and 2 (based on pumped hydro storage), and SS: Seasonal storage technology (based on hydrogen storage).

Accurate modeling of long duration storage has historically been hard

- Several methods have been proposed to improve dispatch optimization for storage
  - State of charge targets
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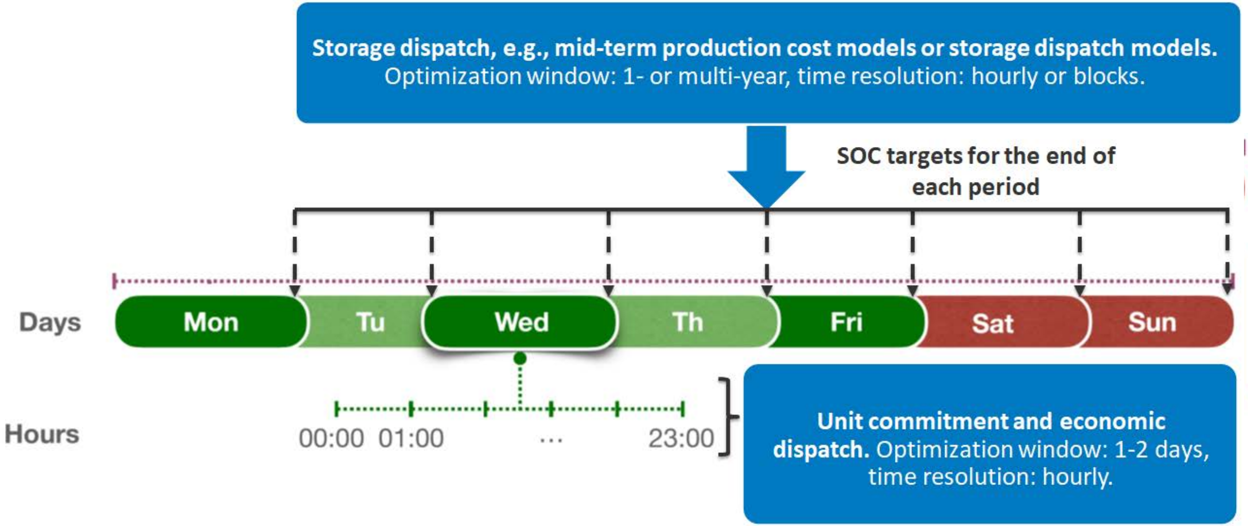
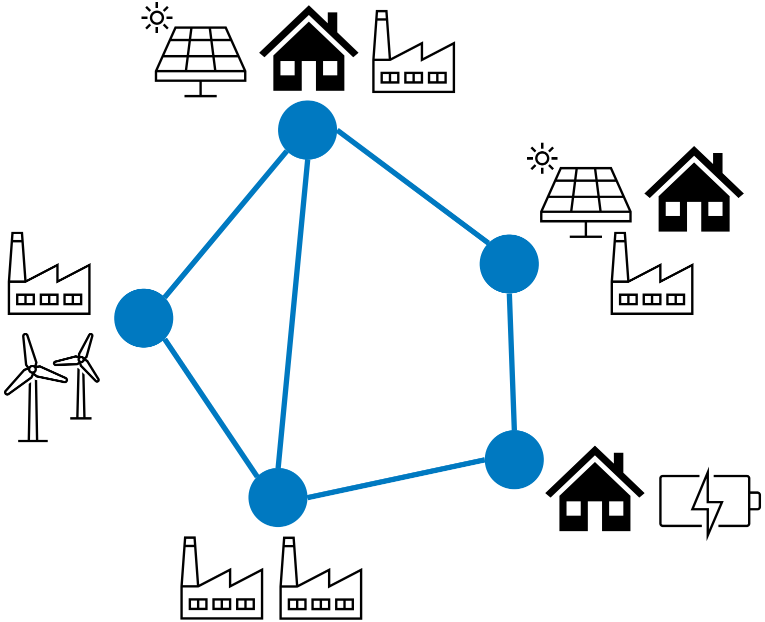


5-Bus Test System

- We modified a 5-bus test system to use for testing long duration storage at different penetrations and modeling methodologies
- Modeled in SIIP::PowerSimulations https://www.nrel.gov/analysis/siip.html
- Scenarios include (all pre-curtailment):
  - 30% each PV and Wind (30% RE)
  - 45% each PV and Wind (45% RE)
  - 60% each PV and Wind (60% RE)
  - 10- or 24- hour battery



Preliminary Results. Do not cite

5-Bus Test System

- Similar to previous work, we find the impact of long duration storage increases at higher variable renewable shares
- We find longer optimization periods reduces total production cost, with increasing impact for longer duration storages and higher variable renewable shares

10-Hour Storage			
Opt. Period	**30% RE**	**45% RE**	**60% RE**
24-hour	38 M$	27 M$	20 M$
72-hour	-2%	-3%	-4%
168-hour	-2%	-3%	-4%

24-Hour Storage			
Opt. Period	**30% RE**	**45% RE**	**60% RE**
24-hour	36 M$	26 M$	20 M$
72-hour	-2%	-5%	-7%
168-hour	-3%	-6%	-8%

Preliminary Results. Do not cite

Results

- To test the impact of forecast errors, we removed 2 thermal units from the 45% RE and 60% RE scenarios to ensure the system was not over-built. This allowed us to better **identify periods of system stress** via times of lost load.
- **Forecasting errors were not found to have a significant impact on overall metrics** of production cost and curtailment in this test system, however we did identify **impactful results during key periods of reliability concern**.

Preliminary Results. Do not cite

Impacts to Unserved Energy

- We added 8% random forecast error in either a systematic over- or under-forecasting method to understand how forecasting errors can impact storage dispatch
- The table shows the percent increase in unserved energy from the perfect foresight scenario. The 30% RE scenario did not have any dropped load.

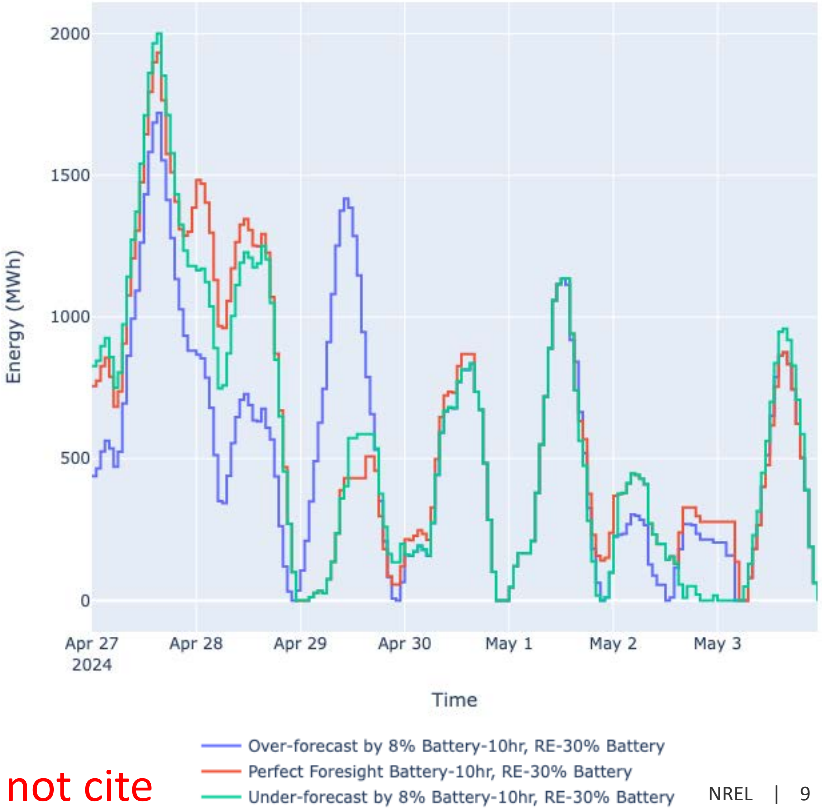
10-Hour Storage		
Forecast Error	**45% RE**	**60% RE**
Perfect	134 MWh	129 MWh
8% over	13%	7%
8% under	34%	0%

24-Hour Storage		
Forecast Error	**45% RE**	**60% RE**
Perfect	170 MWh	129 MWh
8% over	4%	1%
8% under	4%	1%

Preliminary Results. Do not cite

Impacts to Storage Cycling

- Forecast errors were also found to impact the amount of cycling the storage systems, increasing the number of times the storage was fully emptied
- Forecast errors also increased the number of hours the storage spent empty



Preliminary Results. Do not cite

Key Takeaways

- Long duration storage operations will become increasingly important to understand and plan for as variable renewable shares increase
- Standard modeling methods tend to under-represent the value of long duration storage
- Forecasting is an important aspect of long duration storage operations, and in particular can impact reliability of the grid if not well managed. The impacts to reliability were found to be greater than the annual impacts, such as total cost and curtailment, on our test system.

Preliminary Results. Do not cite

Thank You

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NREL/PR-6A40-83126

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Solar Energy Technologies Office. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.

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