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WHITE PAPER

Virtual dams: Harvesting the output of hydropower with dispatchability constraints

Yield more revenue by optimizing energy and capacity to sell to the grid, increase reliability and participate in ancillary services markets

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Opportunity

Water is one of the world's key resources for clean energy. However, certain hydro assets, such as run-of-river hydropower installations or dams operated for purposes other than power generation (i.e., supplying water for irrigation), are unable to maximize their electricity generation capabilities.

Battery-based energy storage can help provide owners of run-of-river hydropower and agricultural dams a way to store the output of these resources – creating "virtual dams." This relatively new application for battery-based energy storage can offer owners new revenue streams, in the form of energy and/or capacity to sell, as well as providing grid services to the electricity networks these assets are connected to. This ensures existing power generation is better utilized, increasing the efficiency and returns of these large facilities.

Solution

"Virtual Dams," Energy Storage Without Massive Built-Out Requirements of PHES

Creating a virtual dam refers to using battery-based energy storage to store hours of energy generated by water flows lacking a hydropower dam for later dispatch. For run-of-river hydropower resources, this means capturing output from the river's natural flows and discharging when is most advantageous. For agricultural or other dams that do not schedule water releases in time with peak power needs, a virtual dam can similarly capture the energy generated during low power demand times – similar to shifting solar output – and discharge it to the electric grid when it's needed and consequently more valuable.

Grid-scale batteries have been deployed widely around the world and use similar technology to that found in electric vehicles, which is built to stringent automotive standards and aggregated at scale to deliver the same electricity storage capability as pumped hydro projects. In addition, battery-based assets can deliver far faster response times – on the order of hundreds of milliseconds – to provide ultra-fast ancillary services in addition to time-shifting hours of power plant output.

By comparison, in areas where hydropower dams exist and the geography allows for multiple reservoirs and related equipment required, pumped hydropower energy storage (PHES) can provide a means of storing dams' output for hours or even days. PHES projects require large-scale civil infrastructure works, typically involving the construction of upper and lower water reservoirs.

However, while new PHES schemes provide plentiful long-duration storage, they do so at high monetary, environmental and timeline costs. For example, the planned 1,000 MW Tehri project in Uttarakhand, India received permitting approval for 292 hectares (721 acres, or nearly 3 sq km), and is still under construction after breaking ground over 30 years ago.

The table below highlights some key differences between the two storage technologies:

	BATTERY-BASED ENERGY STORAGE	PUMPED HYDRO ENERGY STORAGE
SPEED OF DEPLOYMENT	Can be built in 6-18 months depending on scale, with similar regulatory permitting as industrial buildings.	Massive civil engineering structures with large environmental impacts, requiring a complex permitting process that can take years to secure approval before construction can begin
SPEED OF RESPONSE	• Response and ramp times times of less than a second • Installations using industry-standard Li-ion battery modules can cost-effectively store up to 6 hours of electricity • Can provide in parallel both typical ancillary services and faster-response services like synthetic inertia and Fast Frequency Response, which require sub-second response times • Can provide black start and grid forming capabilities	• Can store and provide hours or days of output • Requires seconds to minutes, depending on design, to ramp up to full output • Can provide primary frequency regulation (PFR), which requires responsiveness in the range of seconds. PFR can only be provided when the facility is already in operation
FOOTPRINT	• 1 GW can be deployed in 250 MW increments taking up 5 hectares (12.3 acres or 0.05 sq km) each within 12-18 months • Produce no direct air emissions or wastewater discharge, require no water for daily operations and contribute minimal noise to the surrounding area	• Typical reservoir sizes range between 10-100 hectares (roughly 25 to 250 acres, or 0.1 to 1 sq km) • Theoretically function as closed-loop systems, but must have existing water reserves or available water available to ensure reservoirs are full enough to function, and are thus susceptible to interruptions of service due to drought
SCALABILITY	• Typically ranging from 1 to as much as 6 hours duration storage • Can be scaled from 1 MW to 500+ MW scale	• Typically designed for 5-25 hours duration storage • Scaling driven by siting constraints (i.e., a natural lake with the right altitude)

Virtual Dams' Potential

Unlocking More Revenue Streams for Asset Owners

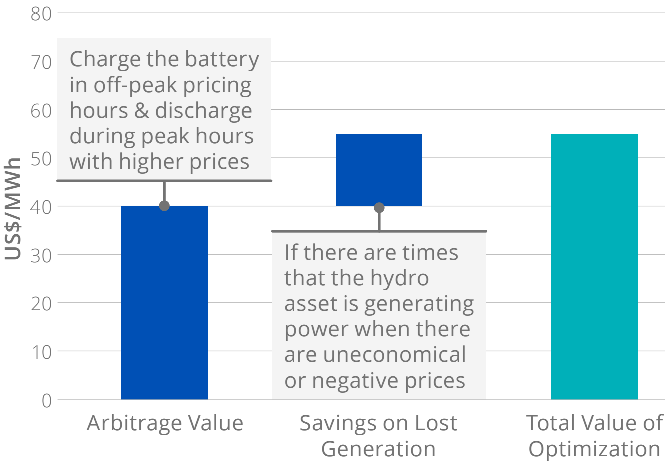
Optimizing dispatch: Run-of-river hydropower assets by definition do not have a dam providing water storage, and by extension, the ability to control when power is generated. In areas where constructing a dam may carry challenging or prohibitive permitting hurdles and community opposition, batteries can store and deliver that output with far fewer social and environmental challenges.

Similar to other renewable energy resources, non-dispatchable hydro facilities can take advantage of time-shifting their output:

1. Arbitrage value can be realized by charging the battery during low price periods and dispatching/selling at high demand periods with higher prices;
2. A run-of-river hydro facility realizes potentially more value with a battery, as it can prevent dispatching power at times when there is no demand and help avoid zero or negative pricing events.

100 MW Run-of-River Hydro Plant
Participate with 20MW in Capacity/Peaking Market and with 100MW in Energy Market

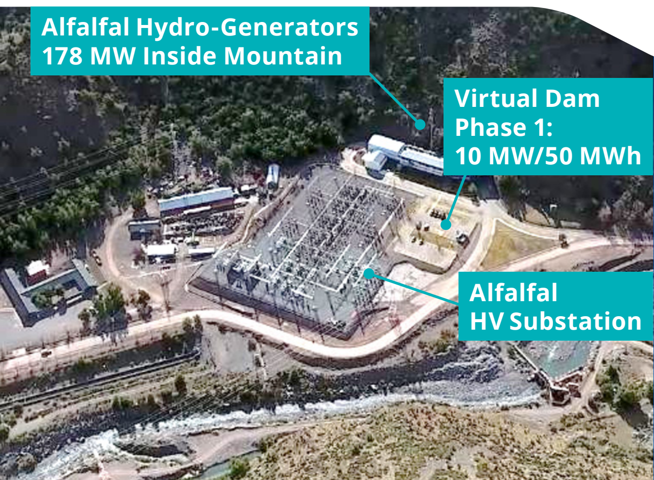
100MW Run-of-River Hydro Plant + 50MW Battery
Participate with 70MW in Capacity/Peaking Market and with 100MW in Energy Market



Tapping into capacity revenues: In markets that recognize generators for capacity, availability, reserve or reliability, only a fraction of renewable generation such as wind, solar and run-of-river hydro facilities' generating capacity can be considered for reserve or reliability needs due to their dispatchability constraints, and consequently only receive a portion of the associated payments.

By creating a virtual dam, a run-of-river hydro plant or an agricultural dam can significantly increase its dependability with the dispatchable capacity reserved in the battery, enabling the hydro plant to act as a peaker and earn additional capacity revenues. The example above shows the additional revenue a hydro plant can earn as a peaker by adding a battery-based resource to their facility.

For example, Fluence has just deployed a Virtual Dam for AES Gener sited at one of their existing run-of-river hydro plants, Alfalfal I near the Chilean capital of Santiago. By providing five hours of firm peaking capacity, Alfalfal is now recognized for its dispatchability and is now able to tap into firm capacity revenues that it could not before.



PROJECT SPOTLIGHT: **Alfalfal I**

SYSTEM OVERVIEW:

- 178 MW Run-of-River Hydropower Plant
- 10 MW / 50 MWh Energy Storage Array
- Customer: AES Gener
- Commissioned: In Progress

APPLICATIONS:

- Flexible Peaking Capacity
- Ancillary Services (Frequency Regulation)

Providing additional ancillary services: Depending on the market, with the inclusion of a battery-based asset at a hydro facility, the installation will be able to participate in more ancillary services markets. This may even yield a higher rate of payment, as battery-based resources provide a faster and more accurate response for frequency regulation than PHES assets and some utilities or networks pay for the faster-response services, which can include Fast Frequency Response or synthetic inertia. Many grid support services require quick and very short duration response in generation and availability of capacity, which a battery-based resource can provide.

Turning irrigation flows into peaking power capacity: Agricultural or irrigation dams are required to release water for farming purposes, and this often may not align with the most economical market prices for power generation. Generation during low or negative market prices can be stored to create additional revenue for such facilities as well. Grid-scale batteries can be deployed in less than a year to capture output and provide both energy and ancillary services, and additionally grid operators can count on generation from agricultural hydropower dams as reserve power.

Potential for Virtual Dams Swells in Latin America, Asia and Australia:

The potential to create value from nondispatchable hydro assets is already being tapped, with projects underway in Chile, across southeast Asia and in Australia. Fluence's team is already helping two power producers access new revenues from their nondispatchable hydro assets.

Based on available data from the International Hydropower Association, Fluence estimates run-of-river hydro assets around the globe totaling roughly 345 GW that could benefit from the addition of battery-based energy storage. In addition, global installed hydropower capacity at irrigation dams is estimated to be more than 80 GW.

Want to learn more on how or where the potential exists to create Virtual Dams? **Get in touch today:**

fluenceenergy.com/contact

ABOUT FLUENCE

Fluence, a Siemens and AES company, is the global market leader in energy storage technology solutions and services, combining the agility of a technology company with the expertise, vision and financial backing of two well-established and respected industry giants. Building on the pioneering work of AES Energy Storage and Siemens energy storage, the company's goal is to create a more sustainable future by transforming the way we power our world. Providing design, delivery and integration, Fluence offers proven energy storage technology solutions that address the diverse needs and challenges of customers in a rapidly transforming energy landscape.

The company currently has more than 2.1 gigawatts of projects in operation or awarded across 22 countries and territories worldwide. Fluence topped the Navigant Research utility-scale energy storage leaderboard in 2018 and was named one of Fast Company's Most Innovative Companies in 2019.

To learn more about Fluence, please visit fluenceenergy.com.

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