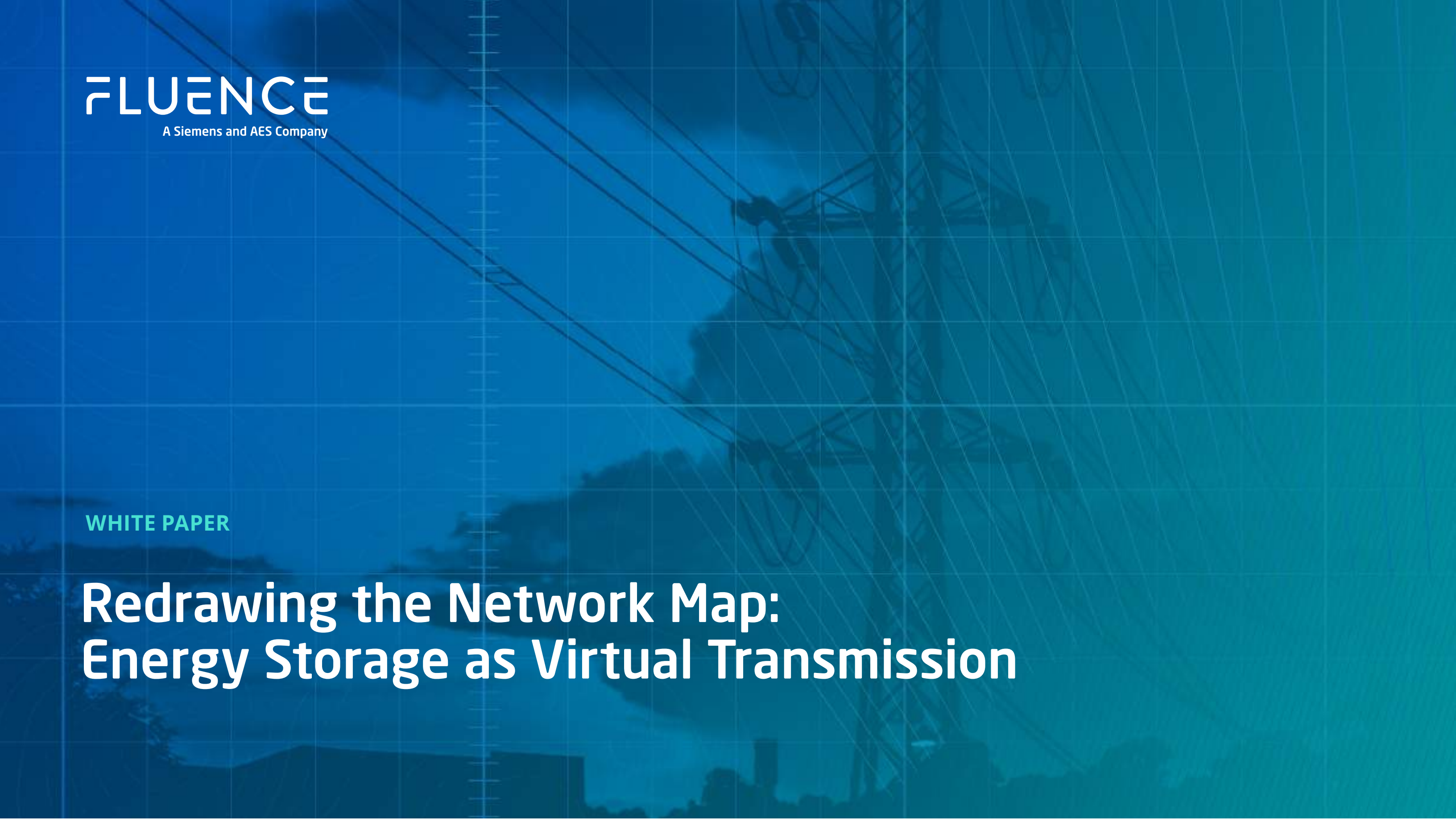

FLUENCE
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WHITE PAPER

Redrawing the Network Map: Energy Storage as Virtual Transmission

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Introduction

In many markets across the world, changes in where and how electricity is generated, where it needs to be sent and how it is used are redrawing the transmission network map in real time. But planners and utilities seeking to accelerate upgrades on unexpectedly busy corridors are confronting all-too-familiar obstacles—long permitting times, challenges in securing easements and disputes with communities on project placement.

Until recently, the majority of discussions around deploying energy storage have focused on how storage can either support or replace generation—to provide ancillary services, peaking capacity, or the flexibility needed to integrate large amounts of renewable energy. But now, transmission companies around the world are increasingly looking at energy storage technology to supplement or even replace the poles and wires that carry high-voltage current from power plants to end-users.

Deploying storage as transmission—a relatively simple, but not widely-known concept—offers networks new flexibility to meet capacity needs. Energy storage is placed along a transmission line and operated to inject or absorb power, mimicking transmission line flows. Used in this manner, storage can take the place of proposed system upgrades or lines that would otherwise have to be built.

Such applications represent a new and vital area in which storage is providing value, offering planners more options and more flexible tools for redrawing the network map around the world.

With names like "virtual transmission" in Australia and "GridBooster" in Germany, projects totaling over 3 gigawatts (GW) of capacity are poised to increase system efficiency and reliability worldwide. They can do so on far faster timelines and with competitive costs and benefits compared to traditional infrastructure.

This white paper examines the current state and future prospects of how energy storage can be used to defer or replace transmission system upgrades, offers examples of where energy storage is already being deployed for these purposes, and provides key strategies for integrating storage in network planning.

Transmission: Some Highways Gridlocked, Others Barely Used

Electricity networks are shifting from the century-old model of power flowing from large, centralized, conventional generation to load centers, to one where new generation is spread out across the network. Solar and wind projects are being sited where sun and wind resources are most abundant, frequently in areas where transmission lines weren't designed to accommodate such power flows. The accelerating influx of zero-marginal-cost resources, such as renewables, is impacting the dispatch of traditional base-load units which is further changing flow patterns on electricity networks.

This redrawing of the map is leading to two key trends:

First, creating areas where additional power flow capacity is needed on key transmission lines at specific areas of the grid;

Second, excess transmission capacity (e.g., underutilized lines elsewhere on the grid) potentially becoming stranded assets, which won't be needed but still have to be paid for. This situation is emerging especially in areas where renewables continue to supplant traditional large power generation sources.

The flood of new decentralized generation—in particular, solar and wind, which both have variable generation curves—is putting the equivalent of heavy highway traffic onto smaller country roads. As a result, networks are quickly becoming congested, in some instances causing solar and wind projects to be curtailed because their output cannot reach load centers.

Meanwhile, similar changes in power flow patterns—from coal or older gas generation being retired—are leaving already-built transmission corridors barely used. Transmission lines are built with an expected full cost recovery time of 25-30 years. But if a line is no longer used, the network owner suffers from low utilization of key high-voltage transmission lines while end customers continue to pay for those assets.

For example, suppose a coal plant is retired for economic reasons or when it reaches the end of its life, and new generation is not sited in the same vicinity. The existing lines used to move that power could be left with a significant amount of capacity to spare.

This is no hypothetical concern. Bloomberg New Energy Finance found that nearly 50 percent of Australia's coal plants will reach reach the end of their useful lives between 2030 and 2040, if not taken offline beforehand for economic reasons.[1] The same situation exists in both U.S. and European markets, where coal plants are being phased out or are retiring within the next several years due to economic or environmental reasons.

Both trends, congestion and underutilization, are problematic for network companies. While the first issue means they may need to find ways to address transmission shortages quickly, stranded assets are a more complicated problem. **If existing assets are shown to be underutilized and aren't providing as much value as originally expected, end customers end up paying more, and network companies will come under greater pressure to spend capital diligently as they work to address network capacity shortage issues.** Changes in generation patterns (i.e., from coal to renewables, hydro and gas) are becoming more sustained, which is increasing the risk of a number of transmission or distribution assets becoming stranded.

Building traditional poles-and-wires infrastructure to add capacity—the typical solution for relieving congestion—is a long and onerous process. Project assessment, scoping and delivery timelines often range from two to six years, and obtaining all necessary permissions (e.g., easements, rights of way, and regulatory approvals) can take 10 years or longer, depending on the project and country.

Meanwhile, network companies continue to look for investment opportunities that offer highly scalable, lower-risk and customer-friendly options to enhance network reliability and security, meet their investment profile, and avoid NIMBY ("not in my back yard") concerns. The need to secure easements alone can significantly extend the timeline of transmission projects, resulting in extended community consultations, the need to seek regulatory approvals or, in the worst cases, lawsuits.

1 The inevitable decline of Australia's coal generation," March 2019: https://poweringpastcoal.org/insights/energy-security/the-inevitable-decline-of-australias-coal-generation

The Solution: Battery-Based Storage as a Transmission Asset

Deploying storage as "virtual transmission" is a little-known and simple concept that offers networks new flexibility in meeting capacity needs. Energy storage is placed along a transmission line and operated to inject or absorb real and reactive power, mimicking transmission line flows. Storage deployed in this manner can essentially take the place of a proposed line upgrade or new line that would otherwise be built (see Figure 1).

Using energy storage for transmission capacity is a new approach to solving line congestion. With storage, hundreds of megawatts of capacity can be added to lines in far less time than traditional assets.

> Storage as transmission offers numerous benefits over traditional transmission infrastructure.

Flexibility, Scalability & Relocatability

FASTER TO DEPLOY

Energy storage systems can be deployed as much as 80% faster than transmission lines—in as little as one to two years for assets 100 MW or larger. Storage systems are not subject to the same arduous permitting and easement processes required for transmission lines. Speed of deployment is particularly useful when local grid conditions are acute, and a solution is needed within one to two years. As storage is increasingly used for residential and commercial applications, ancillary services, and peaking capacity, even larger system sizes for storage in T&D will become standard.

UP TO 80% SMALLER FOOTPRINT

Because battery-based energy storage projects have compact footprints—housed in either data center-like buildings or containerized solutions—they do not have the typical environmental impacts of transmission projects. Avoided impacts include right-of-way and easement issues, visual impacts across large tracts of land, wildlife preservation issues, or the need to cross water or protected lands, as well as the communal benefit of fewer high-voltage cables crisscrossing local communities. A 200-300 MW energy storage project could fit onto a site equivalent in size to only 600 meters of 220 kV transmission line, including easement.[2]

EXTRAORDINARILY FLEXIBLE

Storage assets can be scaled dynamically in terms of size, operations and applications over different planning horizons to flexibly adapt to network conditions. Storage can also be configured in a wide variety of ways to adapt to siting constraints. No other transmission asset class can provide this level of flexibility.

A RELOCATABLE ASSET

Unlike poles-and-wires projects, storage can be sited at a variety of points on a network where grid connection is available. It can also be augmented in place or potentially moved to a new location if load or generation patterns change over a project's lifespan. This attribute adds key option value for network owners and operators in how they deploy capital.

ADDITIONAL SERVICES

In addition to enabling greater dispatchability of generation, storage can also provide reactive power, enabling network operators to better preserve system performance in the event of temporary transmission outages or, in more extreme circumstances, prevent blackout/system black conditions or rolling brownouts. Virtual transmission projects can also provide a range of ancillary services, including frequency and voltage control and special protection schemes, to name a few.

LESS RISK

All of these attributes add up to less risk for network owners. Further, energy storage can provide either the network owner or market participant with revenue streams, while concurrently offering network support, such as ancillary services, capacity payments or arbitrage (depending on configuration and local ring-fencing regulatory restrictions).

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2 Fluence estimate

Cost & Revenue

MORE REVENUE DUE TO SHORTER DEPLOYMENT TIMES

Storage's speed of deployment enables significant energy price reductions faster than is possible with traditional transmission lines. As an example, each megawatt (MW) added on several key Australian interstate transmission lines enables more electricity to be imported or exported across them, helping reduce electricity prices during periods of peak renewable generation. In Australia, deploying 100 MW of storage would take 24 months less than traditional solutions, realizing as much as $34 million AUD of savings for consumers during that period for specific interstate lines.[3]

REDUCE INEFFICIENT DISPATCH OF GENERATION

In a number of markets, congestion on transmission corridors is forcing operators to "redispatch" generation—that is, paying generators to ramp down on one side of congestion and others to ramp up closer to load. Storage deployed along a congested corridor can mimic line flows and reduce the need to redispatch generation, minimizing excessive ramping. For example, in Germany transmission-connected storage is being discussed to reduce the costs of redispatching generation to meet peak needs along congested transmission corridors (see Figure 1). According to the German Network Development Plan 2030 (2019 Update) and Federal Network Agency Plan,[4] installing 1,300 MW of storage capacity on the German transmission grid will lower redispatch costs by 130Mio € per year.

Maximize Value

MAXIMIZE BENEFITS THROUGH OWNERSHIP

Storage offers flexibility of ownership compared to single-use assets, enabling potential owners to access additional services, such as managing renewable resource integration.

A COST RECOVERABLE ASSET

Storage, like traditional infrastructure, can be added to the rate base for cost recovery.

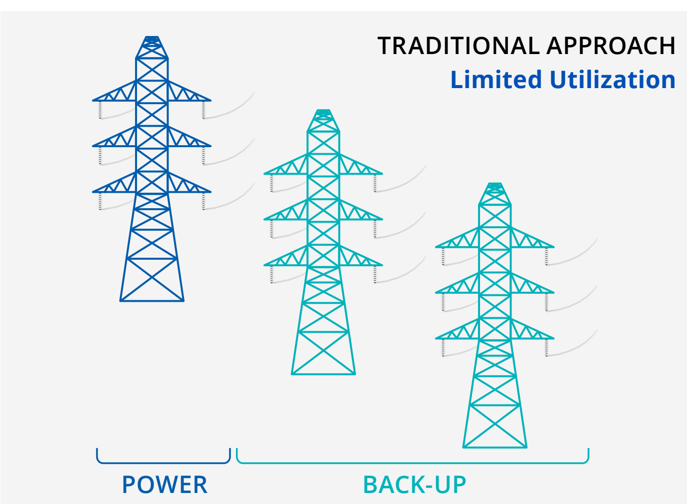
COST-BENEFIT BOON

Energy storage is frequently a less costly option, which can be advantageous in cost-benefit tests.

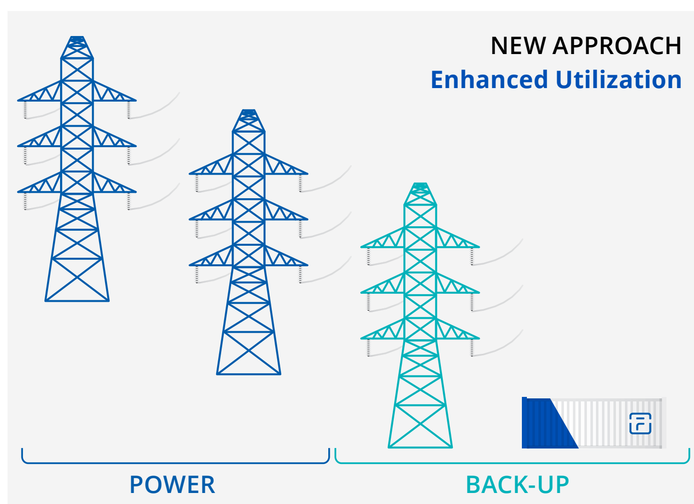
Although energy storage will not always supplant traditional poles-and-wires projects, it offers networks and network planners a powerful and flexible new tool for addressing network issues.

FIGURE 1. Improving Utilization with Virtual Transmission

A. Limited Utilization of Existing Transmission System



B. Enhanced Utilization of Transmission using Energy Storage.



3 Fluence analysis based on comparisons of AEMO published state electricity pricing data in New South Wales, Queensland and Victoria. This sum represents $460 AUD of savings per MW per day.

4 Netzentwicklungsplan 2030 (Stand 2019), https://www.netzentwicklungsplan.de/de/netzentwicklungsplaene/netzentwicklungsplan-2030-2019 , and publicly-available information.

Three Pillars for Including Storage in Transmission Planning

The Fluence team has deployed energy storage solutions globally for over a decade and has extensive experience navigating regulatory processes in many power markets. Based on that experience, we see three key areas or pillars that support the inclusion of energy storage into network planning and, by extension, are critical to accelerating consideration of storage for transmission applications:

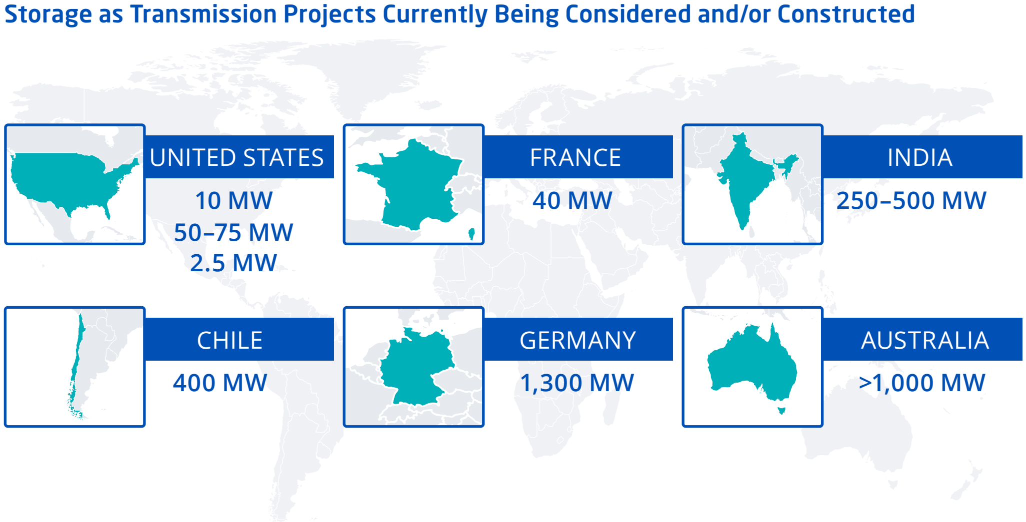
1. Technical capability
2. Inclusion in regulatory frameworks
3. Consideration in planning processes

1. Technical Capability

The technical capabilities of battery-based energy storage are its most mature and well-documented attributes—from providing synthetic inertia more effectively than thermal generation to offering a cost-effective alternative to natural gas "peaker" plants.[5] Further, advances in battery technology continue to drive greater energy density, and battery cell and balance-of-plant costs are also declining year over year. Significant literature is already available studying storage's viability as a transmission asset.[6]

FIGURE 2. 3 GW+ storage as transmission across the world

Storage as Transmission Projects Currently Being Considered and/or Constructed



Energy storage projects deployed over the last few years have helped pave the way for its use as a transmission asset.

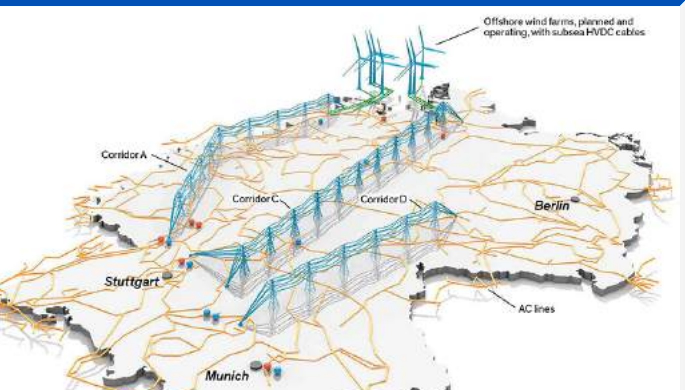
- The U.S. utility Arizona Public Service procured three 2 MW projects for transmission and distribution (T&D) applications—two to provide reliability on distribution feeders serving neighborhoods with high photovoltaic solar penetration, and one enabling the utility to defer upgrading 20 miles of T&D lines.
- Australia's AusNet Services procured a 30 MW, 30 MWh Fluence system at its Ballarat Terminal Station in Victoria. The system is providing grid stability services at a critical transmission junction, as well as flexible capacity to meet the region's daily peak demand needs.

5 Batteries: Beyond the Spin, Everoze Partners Ltd, October 2017.

6 Analytical Studies to Demonstrate Additional FACTS Technologies on the New York State Transmission System, EPRI, May 1996; Application of Storage Technology for Transmission System Support, EPRI, December 2012.

Energy storage's maturity has led multiple countries around the world—India, Germany, France and Australia, among others—to explore even more ambitious applications for storage as transmission. (see Figure 2.)

CASE STUDY



Germany's transmission system operators have proposed several lines across the country, running from the north to the south.

Illustration: Bryan Christie Design. Source: www.entsoe.eu

Germany

In 2019, the German grid development plan, produced by all the transmission-owning utilities in the country, proposed an unprecedented 1,300 MW portfolio of energy storage to ensure grid stability and lower network costs. The storage portfolio, known as "GridBooster," will provide backup transmission capacity as opposed to the grid operators maintaining an entire additional transmission line on standby under N-1 criteria. The GridBooster projects will take the virtual transmission concept to gigawatt scale, and will enable more efficient operation of existing key transmission lines delivering power through the center of Germany.

United States

In the United States, California's Pacific Gas and Electric selected a 10 MW energy storage project as part of a portfolio of transmission solutions during its regional transmission planning process, the first such project chosen to provide congestion relief in U.S. markets.

In addition, in 2019 the PJM Interconnection market in the U.S. held a procurement for transmission solutions to help relieve network congestion, and received proposals for multiple 25-50 MW battery-based storage projects. The proposed projects included options for both standalone storage as well as storage paired with other system augmentation (i.e., line or substation upgrades) in a hybrid approach.

CASE STUDY

The Midcontinent Independent System Operator (MISO) has proposed its first-ever rules on storage as a transmission asset to the Federal Energy Regulatory Commission, as well as its first-ever storage-as-transmission project. Developed by American Transmission Company (ATC), the 2.5 MW/5 MWh project was proposed to take the place of rebuilding a 115 kV double circuit, and would be deployed post-contingency to prevent voltage collapse if the multi-segment transmission supply line were to experience outages. The cost of the energy storage solution was ~30% cheaper than the cost of the traditional line rebuild option; this represents a significant saving for customers in the ATC footprint.[7]

KEY TERMS

N-1 CRITERIA:
N-1 is a grid reliability standard. It means that the system is planned such that, with all transmission facilities in service, the system is in a secure state, and for any one credible contingency event, such as a line or other key asset tripping offline, the system remains in a satisfactory state.

CAPACITY RELEASE:
This term represents the capability of storage to unlock capacity on existing transmission lines that are constrained due to a thermal or voltage conditions. In the event of a contingency, fast-reacting storage units could provide rapid response and in return enable higher transfer of power across the line.

7 If approved, this project would save ratepayers over $3 million in costs over the project's life cycle. "MISO Recommending 1st Storage-as-TX Project," August 2019: https://rtoinsider.com/miso-first-storage-as-transmission-141587/

France

CASE STUDY

French utility RTE is planning its first 40 MW "virtual transmission" project, with the goal of increasing grid integration of renewable energy and optimizing power flows on its network. In this instance, RTE is proposing deploying a pair of storage systems that will operate in tandem at each end of a line.

CASE STUDY

Chile

In Latin America, **independent power producer AES Gener has submitted a proposal for two 200 MW energy storage projects to Chilean regulator Comisión Nacional de Energía (CNE) for inclusion in Chile's National Expansion Transmission Plan**. If approved, the two virtual transmission projects will provide N-1 capacity to relieve congestion on the system; in particular at one location where 700 MW of renewable generation is set to come online on the constrained side of the transmission corridor. The proposal is supported by a report indicating net present value savings of USD $66 million on systemwide generation costs, using the same modeling run by CNE to evaluate new transmission lines. The savings would be generated by more efficient dispatch of the system due to the increased flexibility energy storage can bring to the transmission grid.

2. Inclusion in Regulatory Frameworks

Evaluating storage as a transmission asset allows network companies and planners to use energy storage's flexibility to resolve grid constraints by easing the transfer of power along critical corridors.

However, across markets globally there is a lack of regulatory certainty for network companies to pursue these investments. To boost confidence for the industry to pursue this application, regulators should provide clear directives detailing either storage's demonstrated value (1) as a network asset, or (2) as an asset that can be used in place of or to enhance transmission.

For example, in Germany, the GridBooster projects offer key opportunities to save money for ratepayers by reducing the redispatch of power on both sides of congested transmission corridors and allowing generation to run more efficiently.

However, under current regulations, German transmission companies can only own short-duration storage projects, which limits the assets' use to serving as backup power, not providing additional capacity on the line (like a generator).

In markets where transmission ownership rules allow, projects like these could be scaled up to provide additional capacity on a line, effectively adding lanes to the "road."

Meanwhile, in Australia, transmission companies are governed by "ring-fencing" rules intended to separate ownership of market assets and rate-based assets on the shared network. In order to comply with this regulatory framework, network companies wishing to deploy storage as a transmission asset have three possible ownership options, each with different grid optimization opportunities:

- **Rate-based asset:** To be owned as a rate-based network asset, a storage project must be evaluated and approved through a Regulatory Investment Test for Transmission process. With this option, a project can receive a fixed return but not market revenues.
- **Unregulated asset:** As an unregulated asset, a storage project could qualify, register and participate in wholesale electricity market and earn revenues.
- **Hybrid model:** A network company can own the asset, receive network reliability services from it, and lease it back to a third-party Registered Market Participant to

operate for wholesale revenues the remainder of the year. That model can be reversed as well: an independent power producer or other third party can own the storage asset and lease it to the network company for specific periods of the year to provide reliability services for a fixed capacity charge.

3. Consideration in Planning Processes

Lastly, in order to successfully advance the use of storage for transmission projects, storage options must be thoroughly integrated into all aspects of grid planning and procurement from the very beginning of the planning process. Specifically, developers, owners and other stakeholdes will need to:

1. Ensure proposed storage projects fit specific network needs by stating the case for a project and fine-tuning the applications it will serve.

2. Make the benefits and paybacks clear by providing a quantitative view of the economic savings that storage provides through relieving transmission congestion and enabling power transfers across transmission lines. Additional benefits that should be fully evaluated include: the speed at which storage can be brought online, the time value of money, optionality, and the relocatable nature of the solution.

3. Make comparisons easy. Structure the project so planners and regulators can easily compare the services storage provides with applications they are most accustomed to procuring. In this way, planners and regulators can easily compare storage as a viable alternative to traditional assets.

For example, in Australia, projects using battery-based storage as virtual transmission are being considered alongside traditional poles and wires to add capacity on key interstate transmission lines (referred to as "interconnectors" in Australia).

These lines allow for the import and export of energy between state electricity networks as part of the National Electricity Market. Congestion on these lines has led to periods where one state has excess generation and no alternative but to curtail assets (typically resulting in zero or negative energy pricing periods). Outages or blackouts may also occur where adequate supply cannot be imported. Historically, these interconnectors have been constrained multiple times a year, particularly during peak summer heat, restricting how much electricity can be moved across state lines when it is most needed.

Deploying energy storage along an interconnector would enable capacity to be instantly brought online in the event of a resource or transmission lines tripping offline in one state, enabling imports of electricity from other states to be quickly increased to ensure state system stability. Unlike transmission lines, an energy storage project supporting one of the interconnectors could be scaled to any capacity and augmented over time, as opposed to a line upgrade that must be built all at once based on 10- or even 15-year forecasts of load growth.

Over the past decade, energy storage has been consistently proven to be effective in solving a range of transmission planning challenges. Consequently, transmission entities would be remiss if they omit such assets from the toolsets used to perform load flow modelling and solution assessment. Increasingly, this approach could also be applied to the assessment of static synchronous compensators and synchronous condensers as the flexibility of storage is leveraged to tackle problems solved by those assets.

30 MW/30 MWh battery installation in Victoria, Australia at AusNet Services' Ballarat Terminal Station

Quickly Becoming Mainstream

The future of the grid—the technologies we will use and the investment that will be needed—is now being debated, in some instances fiercely, across the United States and around the world. While many unknowns lie before us, one thing is clear: traditional 10- to 15-year time frames for network planning and deployment are no longer tenable.

Storage as virtual transmission is poised to change the way utilities and planners draw transmission network maps, allowing them unprecedented flexibility in how they design and augment their networks. Transmission network service providers in multiple countries are already working to deploy storage in this manner, in some cases, at scales exceeding 100s of MW. Early projects will inform and accelerate adoption of such applications moving forward, and Fluence is actively exploring projects deploying storage as virtual transmission in multiple geographies.

Australia alone has more than 1 GW of potential for deploying storage to bridge transmission capacity gaps within states and ensure the ability to import and export generation, to mitigate curtailments and outages, and reduce price volatility.

Deployment of energy storage on transmission and distribution networks is expected to scale up quickly. Navigant Consulting predicts 14 GW of energy storage will be deployed by utilities globally by 2027[8] to add T&D capacity and defer or entirely avoid entirely larger infrastructure investments.[9]

These figures reflect the innovation and industry expertise that will be needed to stay ahead of the energy transition as it continues to unfold, taking us in directions we can now barely imagine.

8 Energy Storage Systems Maximizing the Lifetime of Transmission and Distribution Infrastructure," Navigant Research, April 2019: https://www.navigant.com/insights/energy/2019/energy-storage-systems-maximize-td-infrastructure

9 According to Navigant Research, 35.5GW for all infrastructure or 25% out of 35.5GW for direct T&D issues.
"Energy Storage Systems Maximizing the Lifetime of Transmission and Distribution Infrastructure," Navigant Research, April 2019: https://www.navigant.com/insights/energy/2019/energy-storage-systems-maximize-td-infrastructure

How to Advance Storage as Transmission in Your Market

The essential question now facing utilities and planners is how to redraw the map? Where and when is virtual transmission an appropriate choice?

To begin to answer these questions, start with the fundamentals:

- When considering adding new transmission lines of any size, local utilities, network companies and planners should first look at what purpose that transmission capacity is going to serve and how urgently it is needed.
- If an increase in capacity is required to meet growing demand, assess the rate of demand growth. What kind of overload can be expected on a line in years to come, when and for how long? That information will enable stakeholders to evaluate the true growth of load and demand on either ends of the line and the right resource to meet it.
- To ensure a prudent selection, companies and planners should next evaluate if energy storage is a viable option to defer or substitute for a line upgrade. This should include a side-by-side comparison of attributes the desired resource would need (response time, added capacity, one site or a portfolio, anticipated cycles per day and per year). Then discuss with your supplier (or include in your RFP if you plan to hold one) the right storage system sizing and configuration to achieve your goals.
- If a network company decides to consider a storage project or storage as an option for a project, its legal team should review the relevant ownership regulations to understand what is possible under current rules. If ownership rules remain a hurdle, you may also want to reach out to regulators to assess what changes are needed.
- Lastly, look at the big picture. Rather than simply consider storage projects in a one-off fashion, consider whether a portfolio of storage assets could help your organization meet key strategic goals on the timeline actually needed, rather than at the speed of previous asset types.

How will your team redraw the network map in your region with virtual transmission? Contact the Fluence team to discuss what's possible and to delve into these and other findings from around the world.

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