WHITE PAPER

Building Virtual Transmission: Critical Elements of Energy Storage for Network Services

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Introduction

Over the last few years, the concept of deploying energy storage as a transmission asset – or "virtual transmission" – has attracted mainstream consideration in markets around the world. Battery-based energy storage is offering transmission networks new options in meeting capacity needs, offering competitive costs and benefits – and in some cases, greater benefits than traditional infrastructure.

In parallel, regulators in a number of markets are working to understand what functions storage can or should play on their country's or region's transmission networks. Enabling generation projects to move forward is viewed as a key benefit of energy storage as a transmission asset: maximizing the output of growing investments in renewables and delivering more clean energy to load centers where it is needed.

This white paper is aimed at helping regulators, owners and operators of transmission networks move beyond the concepts, understand the broader set of applications a virtual transmission asset could provide, and start assessing what they need from a virtual transmission asset and what ownership structure will be most beneficial.

Update on Projects: Everyone is Going First, So No One is Going First

Many markets around the world are rushing to the starting line as early adopters of virtual transmission. While France is the first market to date building out a portfolio of virtual transmission projects, 6 additional countries are moving to develop their own projects, and some are already at proposal or procurement stage for their first project or portfolio.

FRANCE

IN FRANCE, a three-asset portfolio totaling 32 MW/98 MWh, dubbed Project RINGO, is under construction for RTE's network for completion in 2020. This pilot project is focused on congestion management at the transmission system level.

GERMANY

IN GERMANY, an unprecedented 1,300 MW portfolio of energy storage known as "GridBooster" was proposed in 2019 to ensure grid stability and lower network (i.e., redispatch) costs. As a first phase, three projects totaling 450 MW have been approved for procurement by TransnetBW and TenneT to provide backup transmission capacity, as opposed to the grid operators maintaining an entire additional transmission line on standby to provide N-1 contingency relief.

CHILE

IN CHILE, AES Gener, in consultation with Fluence, has proposed 500 MW to the 2020 National Transmission Expansion Plan. Deployed in blocks of 100MW along two different transmission corridors, these systems will release capacity on the lines by providing N-1 contingency relief with batteries instead of additional lines. Employing the same methodology used for proposed poles-and-wires transmission projects, AES Gener found that the capacity additions would provide an expected net present value of US$400 million to the national grid dispatch costs.

COLOMBIA

IN COLOMBIA, the Ministry of Energy issued a public tender for a 50MW/50 MWh virtual transmission asset. Congestion in the Atlantico region, where transmission upgrades have been challenging to permit, is causing increased network costs as out-of-merit generation is dispatched to ensure system reliability. The virtual transmission asset will relieve that congestion and increase the regional grid's flexibility by providing N-1 contingency relief. This will allow grid operators to dispatch the lowest-cost energy generators while maintaining reliability.

AUSTRALIA

IN AUSTRALIA, multiple projects are under consideration.

- The government of Victoria is working to procure a single large virtual transmission asset under its System Integrity Protection Scheme (SIPS), to allow additional import of electricity over the Victoria to New South Wales Interconnector (VNI) of up to 250MW at peak times.
- Separately, in response to the Australian Energy Market Operator's call for non-network options to upgrade the VNI, Fluence submitted a proposal to deploy two 250 MW virtual transmission assets to work in tandem, which together would add 250 MW of bidirectional transmission capacity to the line.

U.K.

IN THE UNITED KINGDOM, National Grid is working to procure 200 MW of flexible resources to mitigate congestion and facilitate higher power flows on the existing UK grid, notably along the England-Scotland border.

As these examples show, most of the initial virtual transmission projects are being proposed to meet a need emerging from the changing generation landscape and clean energy transition: to better manage renewables output and work around transmission congestion in lieu or ahead of a network upgrade. In short, from being considered a niche application of energy storage few years ago, today the use of storage in transmission networks is coming of age across the world. Several countries are not just considering but actively moving ahead with projects, showcasing the value of this application.

In addition, Europe is already looking ahead to future projects. In July 2020, The European Commission voted overwhelmingly to adopt a strategy report putting energy storage at the heart of its decarbonisation agenda[1] - in particular, emphasizing energy storage deployment as a possible alternative to traditional grid expansion strategies and urging member states to encourage larger storage projects as traditional infrastructure projects face resistance and delays.

1 https://ec.europa.eu/energy/topics/technology-and-innovation/energy-storage_en

What is Virtual Transmission? A Refresher

"Virtual transmission" is the utilization of specifically configured battery energy storage systems in place of transmission capacity to provide combinations of capacity, services, and capabilities that achieve greater value than traditional solutions.

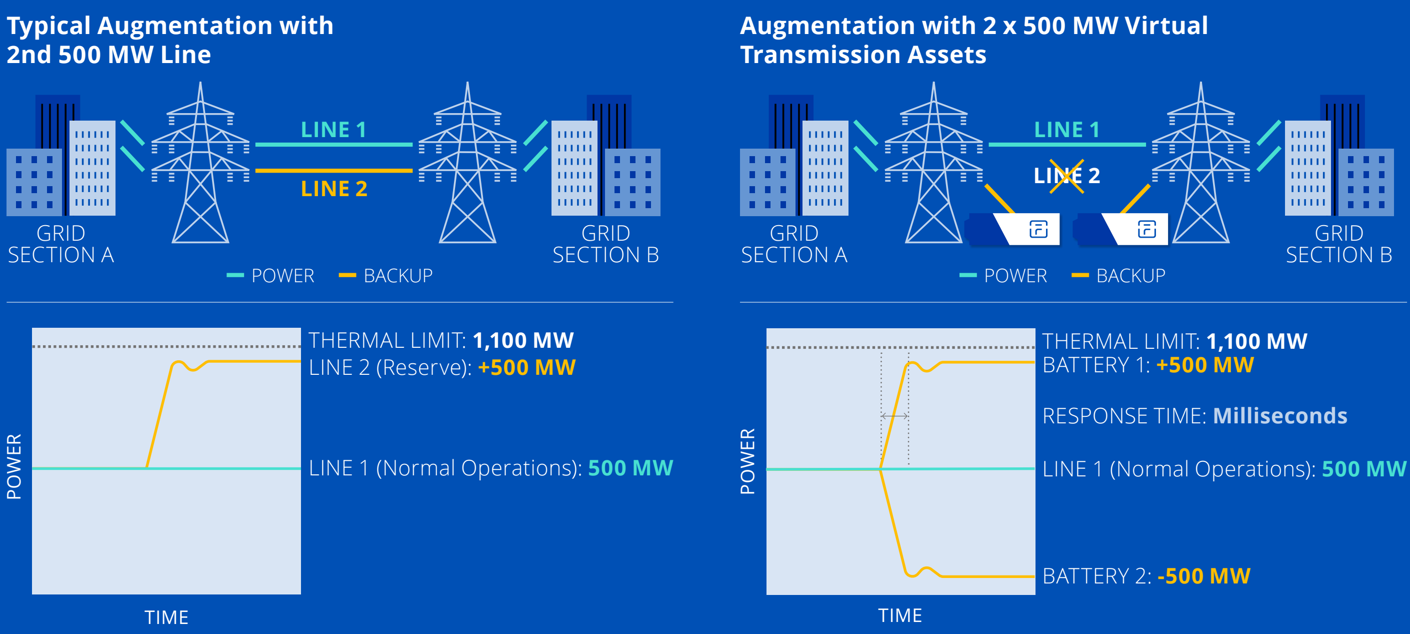
Virtual transmission solutions enable networks to defer or avoid building new lines, operate existing lines closer to their thermal limit with active power support, and provide additional benefits such as black start capability, reactive power support and dynamic power factor control. Such solutions are also able to follow signals from a variety of transmission grid controls.

The value of energy storage comes from its scalability and faster speed of deployment than traditional infrastructure. This enables networks to stage or scale deployment, add capacity as needed, avoid excessive construction costs and permitting challenges often associated with new lines, and manage capital outlays and reassess needs based on how load grows in comparison to projections.

Through detailed power flow simulations and optimization studies[2], planners can model energy storage's impact on transmission systems and identify where it would best support the local grid through direct interconnection, as well as provide positive cascading impacts on adjacent substations via their interconnections.

2 Siemens Power Technologies International, http://siemens.com/power-system-consulting

FIGURE 1. **Example: Meeting N-1 Contingency Criteria with Virtual Transmission**



Three Critical Elements of Virtual Transmission Assets

1 HIGH AVAILABILITY

3 CONTROLS FOR PROTECTION OF SYSTEM

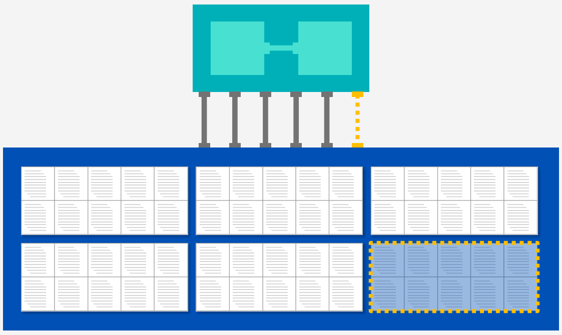
2 ABILITY TO OFFER A WIDE RANGE OF SERVICES

For energy storage assets to date, availability has been as much a commercial concern as a core operational one, focused on delivering ancillary services or shifting generation output for peak needs. Availability is very important, but the grid can continue functioning if those assets are unable to perform due to maintenance or unforeseen downtime. As storage deployments shift to transmission network applications, availability becomes an extremely important item for the reliability of the grid.

The Highest Availability

For virtual transmission assets, availability must be assured at rates that transmission operators are used to receiving from their other assets, in the range of 99.99% availability. This requires a supplier to have sufficient depth of knowledge at the high voltage, medium voltage, and battery system levels to design and deliver a solution with sufficient responsiveness and redundancy to match traditional transmission asset performance.

FIGURE 3. **Example Layout for a 500 MW Virtual Transmission Asset**



Robust Controls for Protection of System

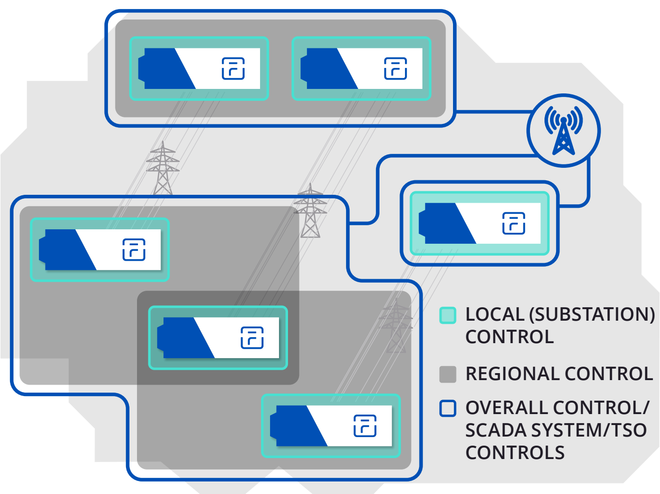
To ensure protection of the larger transmission system, a virtual transmission asset must be able to interact with transmission system operator (TSO) controls and receive dispatch signals from multiple transmission system levels, from central SCADA instrumentation down to the local substation control level:

- **Local controls**:
  needs to act ultra-fast in millisecond-range via inverter-based controls; asset receives signals directly from substation, or via measurements from protection devices or additional meters and processed locally

- **Regional controls**:
  needs to act within 100s of milliseconds; aligned regionally, able to dispatch batteries in small swarms to meet local needs, while considering direct impacts on the nearest lines and substation(s); includes limited implementation of local measurement devices

- **SCADA system and/or TSO controls**:
  needs to act within seconds, slower reaction time due to full optimization of all assets and operation in a large swarm; virtual transmission asset(s) integrated into overall TSO controls to maximize benefits and minimize corrective needs

FIGURE 2. **Levels of Battery Dispatch/Control**



A Large Menu of Capabilities: Storage Applications for Transmission

Battery-based energy storage assets offer a wide range of transmission-focused applications. Though a number of these functions do not currently have a clear path to commercial compensation, they are technically available and can be stacked within one system.

PEAK LOAD RELIEF

DEFINITION: Injects power downstream of thermal constraints during peak hours

KEY BENEFIT: Avoids or defers new transmission capex to meet load

N-1 CAPACITY RELIEF

Including interconnection security and reliability and special protection schemes (pre, mid and/or post-contingency)

DEFINITION: Automatic power injection to support grid stability during contingency

KEY BENEFIT: Increases the operational capacity of existing line, creating more value from existing asset(s)

CONGESTION MANAGEMENT

DEFINITION: Injects power downstream of congested transmission facilities

KEY BENEFIT: Reduces net load payment, adjusted production costs (i.e., redispatch) or other congestion-related costs resulting in customer benefits

DISTRIBUTION SYSTEM RELIABILITY

DEFINITION: Injects real and reactive power at feeder level to maintain voltage stability and improve power quality

KEY BENEFIT: Minimizes “voltage stiffness” and enables better integration of solar DERs

BLACK START

DEFINITION: Provides black start capability to the larger grid

KEY BENEFIT: Enables reassessment of cranking path definitions

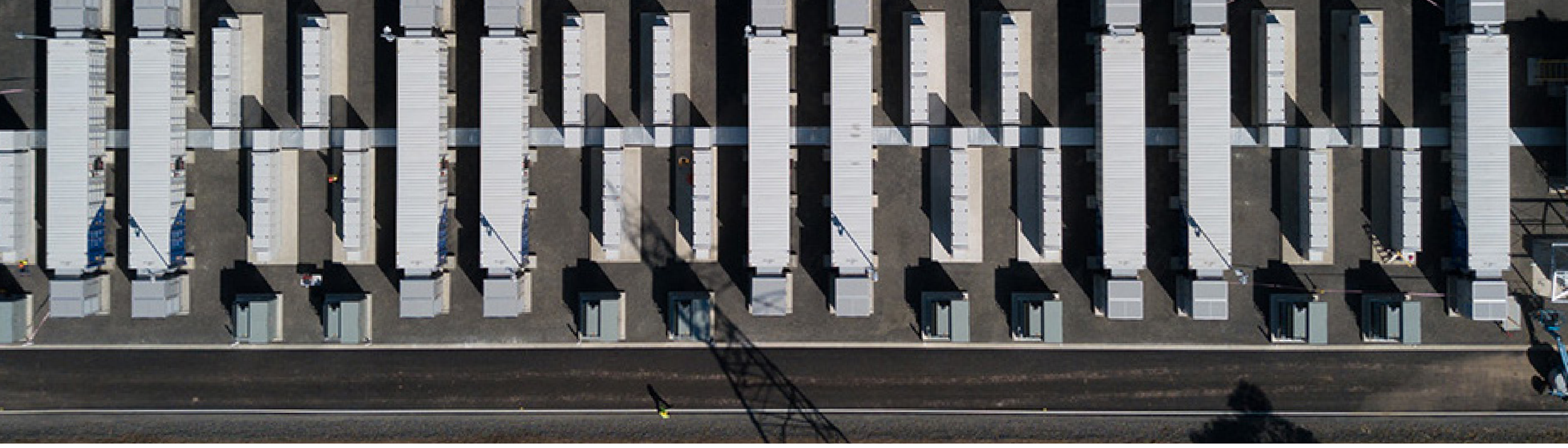
GRID RELIABILITY/ANCILLARY SERVICES AND OTHER REGULATION FUNCTIONS

(V, f, voltage angle, pf correction)

Note: some services uncompensated, others sourced via frequency and capacity markets

DEFINITION: Frequency response/regulation, current injection or voltage injection operation mode, or other reliability standards requiring fast response

KEY BENEFIT: Improving transmission reliability and related metrics



Getting Additional Value From Virtual Transmission

Building the ”jobs to be done” framework for a virtual transmission asset should start with the “base” -- the most critical needs to be addressed in the immediate area/region or the larger market.

Typically, an asset is first envisioned to provide **active power**, relieving existing assets of the need to hold back capacity for N-1 contingency states.

The next layer could be providing **reactive power** to correct and control voltage when significant deviations occur, such as when a generator trips offline or the generation mix changes across the day.

A third layer would be additive capabilities for the local or regional network, such as **black start** or **grid-forming** capabilities. Black start capability from a battery can replace that provided by expensive backup generation (i.e., diesel or LNG). Where local interconnectivity is limited, grid-forming capability enables operators to temporarily “island” a portion of the network while normal operations are restored.

Virtual transmission assets could provide all these services, delivering value to local and regional transmission systems through better use of the existing grid.

Maximize Benefits of Your Virtual Transmission with the Right Ownership Structure

Accessing the most services – and by extension benefits – from a virtual transmission asset may be the result of commercial structures, and the rules for ownership can vary by jurisdiction.

NETWORK-OWNED: The first model to take hold has been where a transmission utility direct procures/owns the asset, and a third party offtakes services from it. For example, in Australia, transmission network companies can either own assets for network services, which receive a regulated return, or provide market services via their unregulated businesses, but cannot own assets to do both. As a result, the Ballarat “big battery” was procured and owned by the unregulated arm of transmission company AusNet Services. EnergyAustralia, a generator and retailer, then secured an agreement with AusNet Services to procure merchant services from the battery.

In Germany, because German transmission utilities cannot own assets that deliver market services, the GridBooster projects are currently limited to network services such as N-1 contingency relief.

THIRD-PARTY OWNED: In markets where a transmission utility cannot directly own energy storage assets, the reverse structure could apply, where a third party owns the asset and the transmission utility procures network services from it.

SHARED OWNERSHIP: A transmission utility and a third-party offtaker can share ownership over a long timeframe, where a portion of the system is reserved for specific network services, and the remainder of the system is available to the offtaker for market participation.

BUILD-OPERATE-TRANSFER: A transmission utility can own a virtual transmission asset for a set period, then transfer full ownership to a third-party offtaker with fully defined applications and revenue. This approach would enable a TSO to defer or avoid more costly and intensive network upgrades and afford an offtaker the opportunity to buy into markets as they grow.

Potential Pain Points

Parties developing a virtual transmission asset may face several obstacles that the Fluence team has observed while advising proponents, networks, and system operators around the world.

Regulatory/Market Issues

In some markets, limited or unclear local or regional regulations governing how transmission companies can own storage could limit what functionality an asset can provide or require rule changes to allow storage ownership. In many cases, the rules were designed for poles and wires and synchronous generation, not considering that batteries could provide both these functions.

Market-based revenue streams for storage in transmission or distribution applications are new and often difficult to determine. For regulated assets, revenues must be approved by regulators, which may add significant proposal and approval time to a project.

Transmission operators may be able to access or provide services through their assets that they could not through assets owned by generators; however, this may lead to **competition for interconnection or revenue** between transmission utilities and generators.

Technical Concerns

From a technology perspective, battery-based energy storage may require overbuilding for transmission applications, with redundant system layouts or extra capacity to ensure the desired level of availability and services, which could add cost compared to generation-focused assets.

As noted previously, for more complex transmission system designs, a virtual transmission asset would need to be able to receive dispatch instructions from local, regional, and TSO-level controls. This requires battery asset controls that can respond with different reaction times – in the millisecond range for local dispatch.

Start Assessing Virtual Transmission Solutions for Your Network Needs

Energy storage as virtual transmission is opening new opportunities for both network planners and potential offtakers, with projects ramping up quickly at both the megaproject and portfolio scale.

As regulators, owners and operators of transmission networks consider how to manage congestion or add critical transmission capacity needed on networks at specific interfaces, we encourage them to reach out to the Fluence team to gauge how a virtual transmission asset can provide new options for network planning needs.

Fluence as a company grew out of Siemens, with a team that draws on and builds on Siemens' 100+ years of **supporting transmission utilities around the world**. With over 12 years' experience of deploying grid-scale energy storage assets, Fluence's team has deep expertise in deploying energy storage at the high- and medium-voltage level, providing the 99.99% availability and high durability required for the most demanding transmission applications.

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.