



VERTIV WHITE PAPER

How to Maximize Revenues from Your Data Center Energy Storage System with Grid Interactive UPS

Arturo Di Filippi, Global Offering Manager

Luca Valentini, Global Offering Specialist

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Abstract

The power generation industry is undergoing a dramatic change as renewable sources, distributed generation, decarbonization and demand increases are transforming traditional sources of energy. The reduced inertia present in the grid, due to the decommissioning of large power plants and the intermittency of renewables, poses significant challenges to its stability. As a result, frequency variations caused by momentary imbalances are higher and more recurring.

Traditional frequency regulation may not be able to provide fast enough response to keep the frequency within specified limits; therefore, faster reacting frequency containment reserves are needed to provide a quick response to sudden frequency variations and to increase or reduce the electricity demand within a few seconds.

Data centers and other types of critical infrastructure have a key role to play in this shifting energy landscape and **are the ideal candidate to implement grid balancing services**. This is due to the presence of assets such as battery energy storages, which could be maximized to generate new revenue streams as well as cost saving opportunities, and ultimately alleviate grid infrastructure constraints.

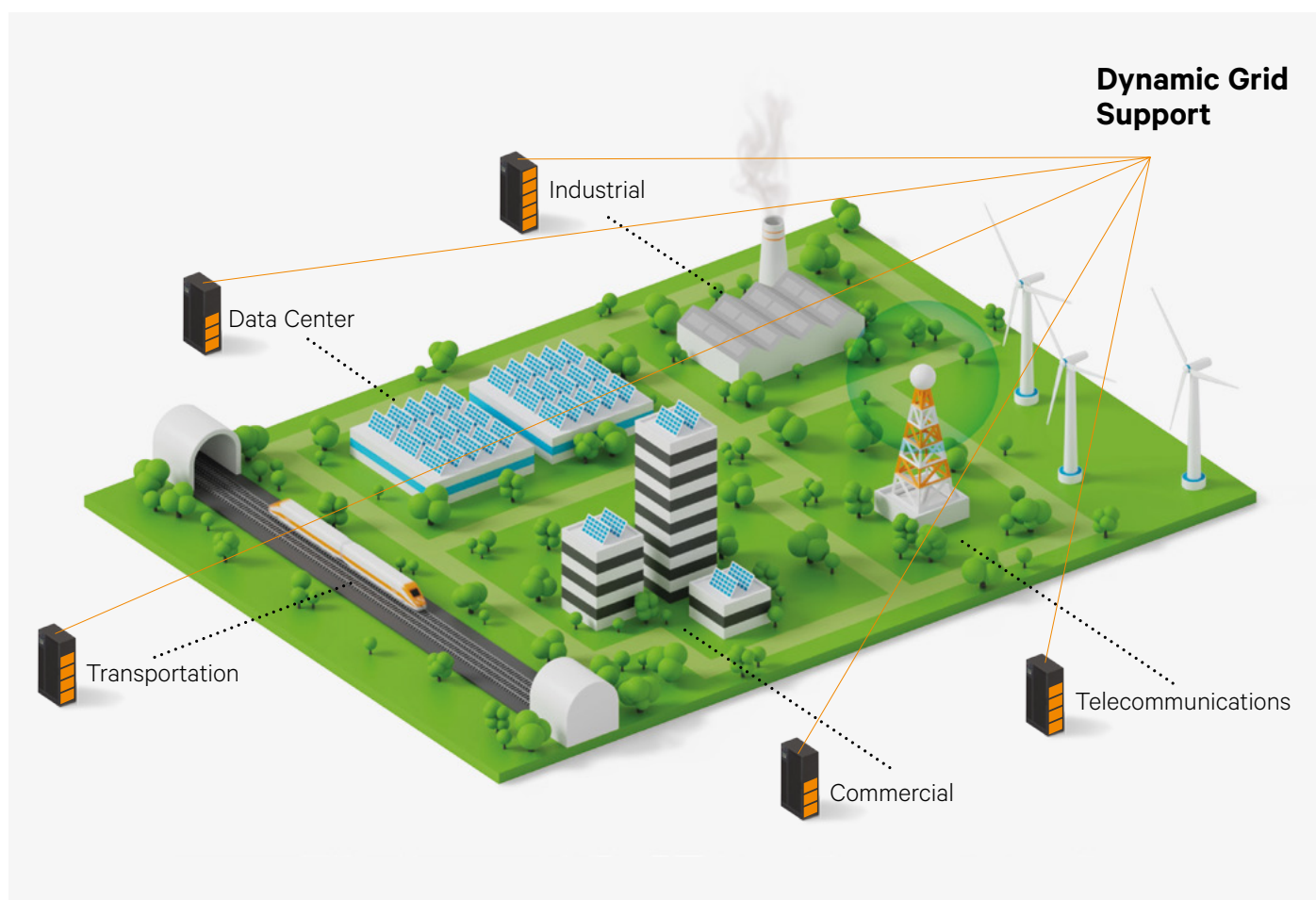


Figure 1. Grid stability in the changing energy landscape

A grid interactive UPS with a properly sized energy storage system can easily provide a fast-enough response to meet the needs for frequency containment, support a variety of income generating services and allow cost savings opportunities through demand management.

By adding grid services capabilities to the UPS, Vertiv enables value creation for data center owners. In this paper, we will present the recent improvements in grid support technology and review the new interactive functionalities of the Liebert® EXL S1 UPS with Dynamic Grid Support for applications in Europe. Extension to other markets (US, APAC) is possible and directly related to specific regulations by region.

1. Context: Energy Storage Market Segments Across Europe

In the last ten years, the electricity industry value chain in Europe has undergone notable changes. In addition to markets opening for competition across and within borders, networks must now be operated by separate entities, clearly separated from electricity suppliers.

Needs and goals of Electricity System Operators (ESO), Transmission-System Operators (TSO) and Distribution System Operators (DSO) translate into opportunities for businesses and consumers to participate in this transformation, by providing grid balancing services and taking advantage of energy storage applications.

Balancing services guarantee the power supply matches the actual demand, ensuring the stability of the grid and allowing for both revenue generation and energy savings. Participants in grid balancing programs contribute to decarbonization and transition to green energy, securing the supply of electricity by addressing the unbalance related to renewable power generation, in turn supporting global sustainability. Ancillary services can be advantageous for any asset that consumes electricity and is connected to a meter. These devices, represented in figure 2, are known as **“Behind the Meter” (BTM)** and differ from **Front of the Meter (FTM)** ones by their final use of destination. In simple terms, behind the meter refers to the power used on site, on the energy user's side of the meter without passing through it. Conversely, electricity on the grid or utility side

has to be measured before reaching the end user and is therefore defined in front of the meter.

FTM systems are for instance battery energy storage devices specifically deployed to provide grid balancing services of various types (peak shaving, frequency control, demand management) with the aim of providing a return on the initial investment in a limited period. BTM systems are instead connected to regular utilities for purposes that lie outside of exclusively supplying ancillary services. The battery energy storage associated with the UPS, dedicated to support the load in case of utility failure - but most times not used during standard grid operation - is a behind the meter system. Battery usage could be maximized and extended to other operating modes, when the grid is present but unstable, or when specific market conditions favor disconnection from the grid.

For data centers owners there are interesting opportunities to exploit BTM systems to participate in revenues generating programs such as fast frequency response (see section 1.3). In addition, BTM assets can contribute to decrease electricity costs through proper demand management (peak shaving, energy arbitrage), by storing energy in the batteries to balance supply and demand. In times of low demand or high supply, energy is fed into storage, from which it is released at times of high demand or low supply. Alternatively, the battery can be discharged through controlled energy management when the electricity price is high and recharged when it is low.

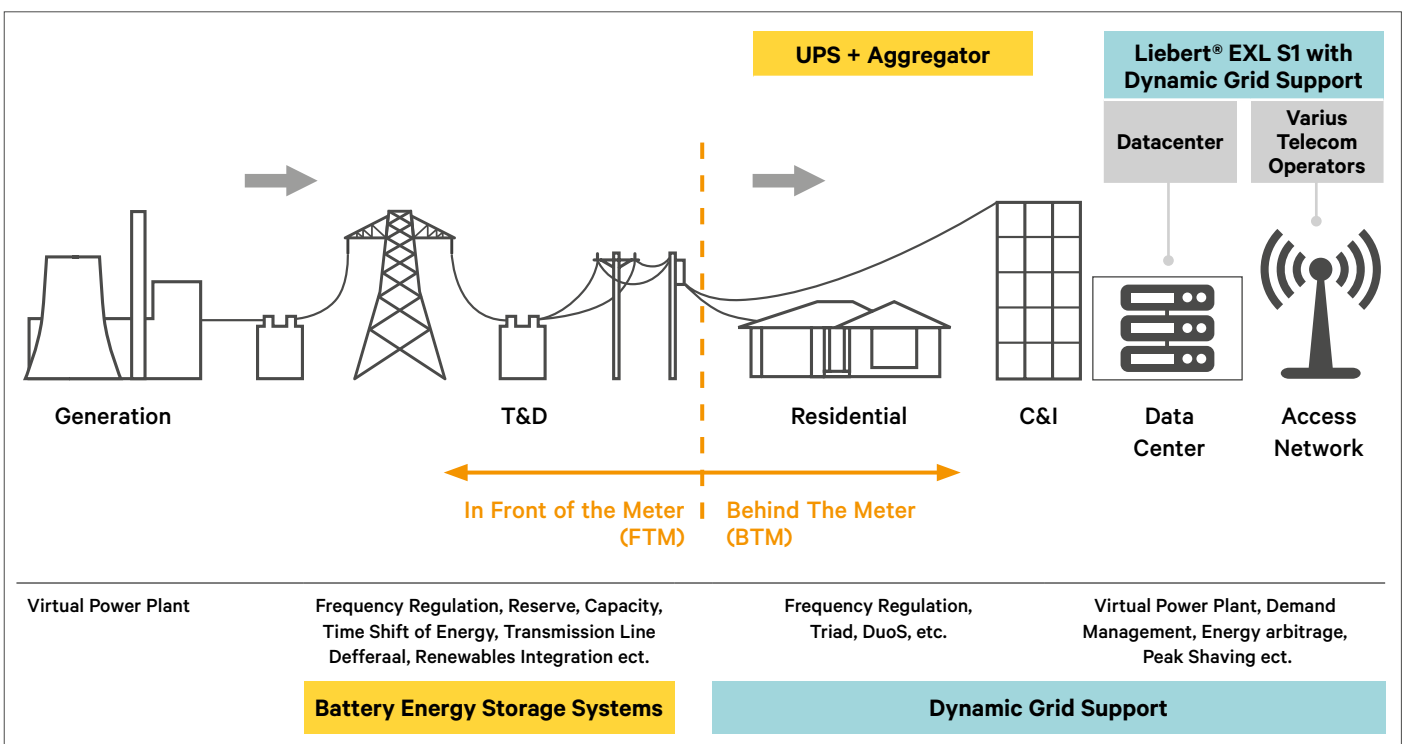


Figure 2. Energy storage market segments within electricity supply chain: FTM vs BTM

1.1 Demand & Response Services to Target Grid Stability

Grid supply is regulated by two main parameters: voltage, 400V/480V for low voltage distribution, and frequency, set at 50Hz/60Hz.

System frequency changes when there is a mismatch in the energy added to the system by generators (supply) and the energy taken off by demand consumers (demand). When supply is higher than demand, frequency rises and vice versa. Traditional frequency regulation relies on the energy reserve, a contingency able to provide additional back-up power to ensure security of electricity supply.

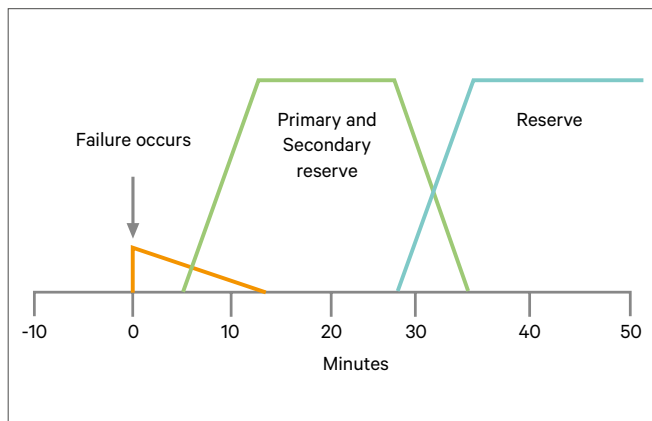


Figure 3. Generic representation of frequency response reserves following a grid failure event

Recently, faster reacting frequency response reserves are needed to provide a **quick response** to sudden frequency variations and increase or reduce the electricity demand within a few seconds (primary reserves) or minutes (secondary reserve).

Demand and Response services can be broadly categorized to target **Frequency Control (Fast Frequency Response)** and **Demand Management**.

In **Fast Frequency Response** programs, the UPS battery storage systems are used to accumulate energy and release it instantaneously according to the following regulations:

- 1. Dynamic Frequency Response** is a continuous service used to balance the system in real-time with an amount of power proportionate to the frequency deviation, constantly adjusted second by second. This service results in continuous positive and negative power variations to control the frequency within the operational limits, remaining as close as possible to 50Hz as shown in figure 4.
- 2. Static Response**, instead, is triggered when the frequency operational limits (specifically over or under frequency values) are exceeded and adjusted with a fixed amount of power.

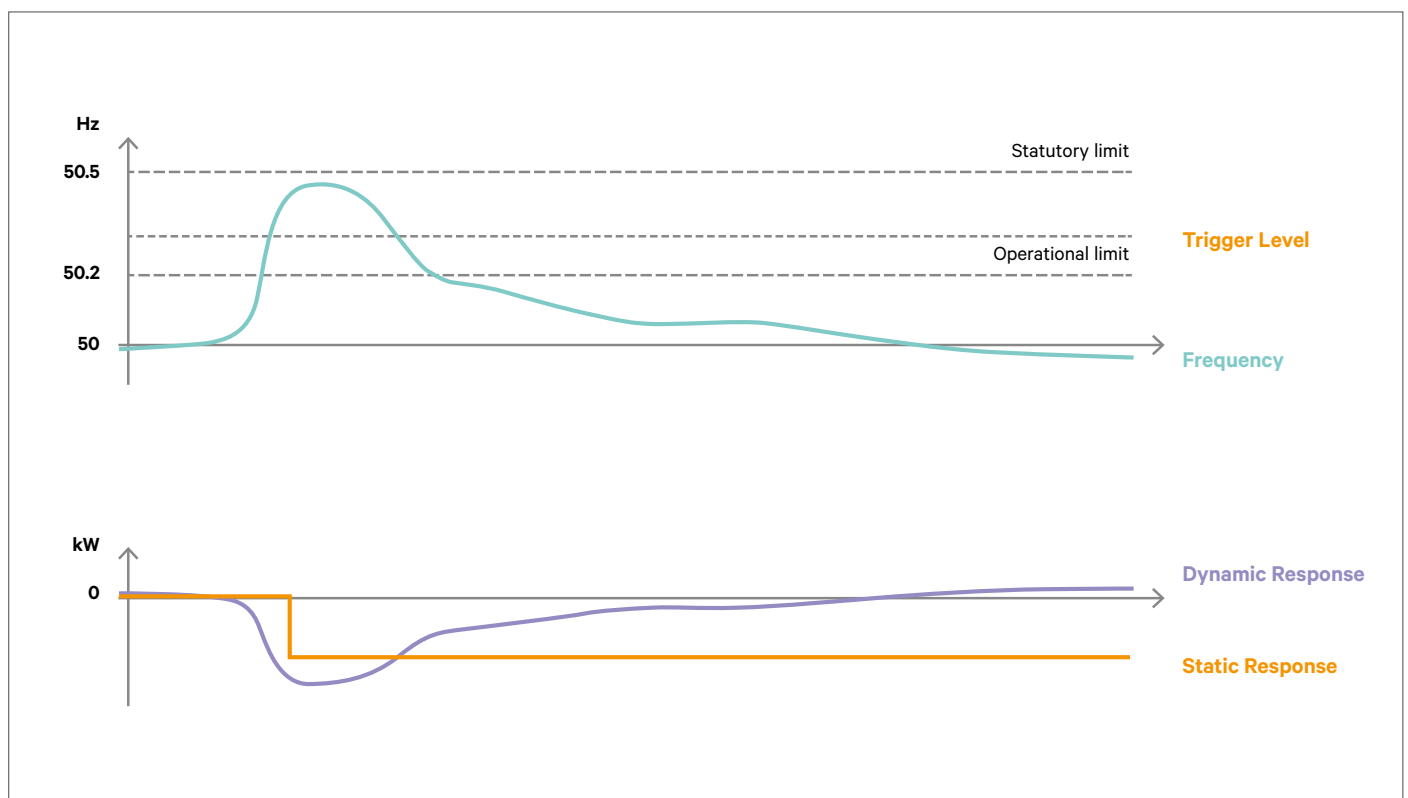


Figure 4. Static and Dynamic Frequency Response

Demand Management - also known as **Energy Arbitrage** or **Peak Shaving** - is an alternative approach to match electricity supply and demand by reducing electricity demand in times of scarcity or high energy costs.

There are two types of programs for the application of demand management: **price-based programs**, where consumers adjust their energy consumption according to the changes in electricity market price, and **incentive-based programs**, where earnings are provided through interruptible contracts where consumers are paid to shift or reduce their energy consumption.

1.2 Areas of Opportunity for End Users in the Electricity Market

The European market programs for balancing services vary for each country. As a general rule, energy markets are governed by a combination of frequency-based balancing services and slower reserve services (> than 30 minutes response time). The electricity market and energy providers define the speed of the response range to participate in the frequency control program through grid services.

In exchange for contributing to programs aimed to adjust the power demand, participants receive a regular financial payment based on the contractual size to be employed for such services (“capacity” payment), and in some countries they may also receive a bonus bundle for being enrolled. When providing grid balancing services, participants receive additional “energy” payments based both on how fast they react to grid frequency variations and on the amount of

energy reduced. Payment amounts vary depending on the program rates offered by the grid operator or energy service provider, which will ensure the end user receives the maximum financial benefits for participating in that specific program.

1.3 Revenue Generation and Cost Savings in the UK: A Prime Example

In Great Britain, the National Grid is the system operator responsible for maintaining the frequency response of the power system within acceptable limits. At present, this is achieved through **fast, high, primary** and **secondary** response services:

Fast Frequency Response (FFR): Response within 0.5 seconds of an event, can be sustained up to 10 seconds.

Primary response: Response within 1-2 seconds of an event, can be sustained up to 30 seconds.

Secondary response: Response within 30 seconds of an event, can be sustained up to 30 minutes.

High response: Response within 1-2 seconds of an event, can be sustained up to 30 minutes.

The **Enhanced Frequency Response (EFR)**, targeted to guarantee the provision of 100% of the active power output within one or two seconds following a measured frequency deviation, has been extensively used in the recent past, while the program is currently under revision and replaced by the Fast Frequency Response.

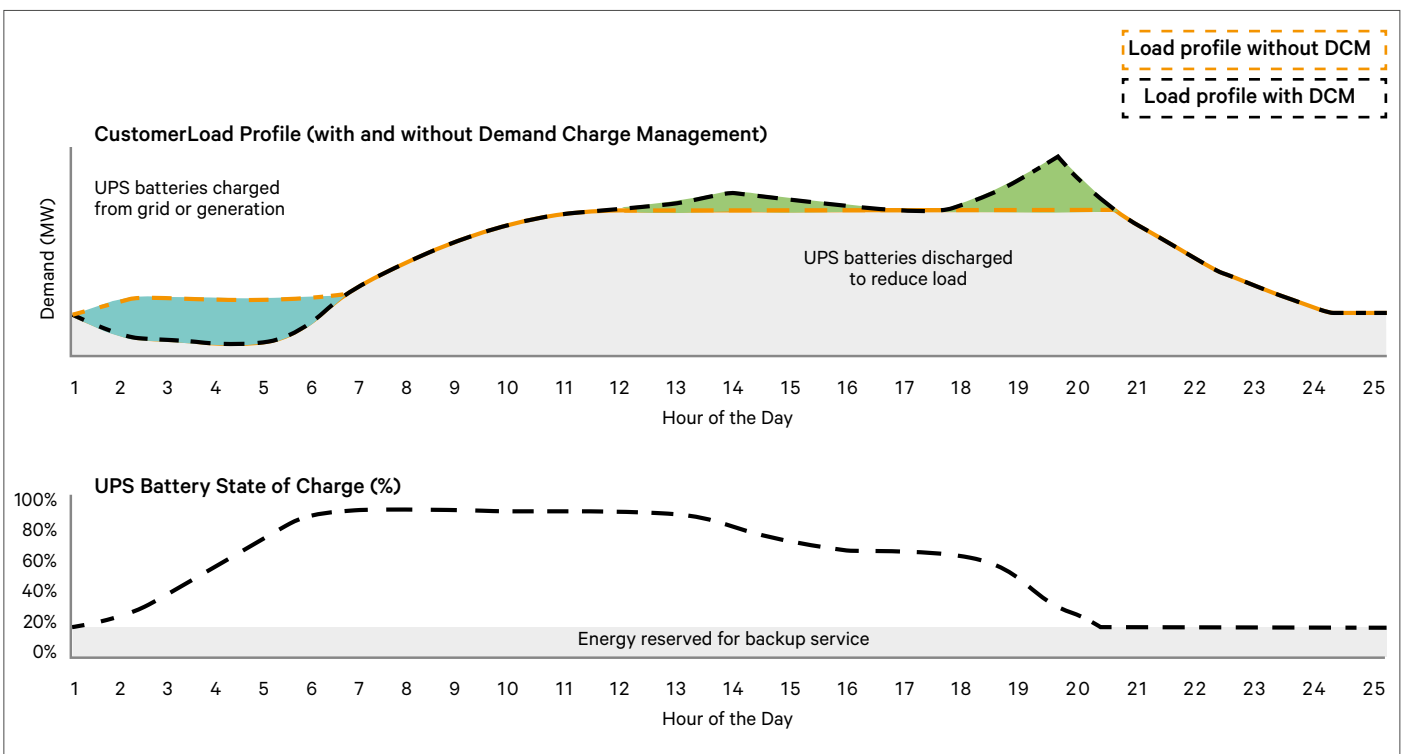


Figure 5. Customer load profile for Demand Management (Peak Shaving)

The **most lucrative** services are related to **fast frequency response**, requiring active power to be adjusted in a 500 ms to 1s time frame in reaction to over and under frequency detection. In similar conditions the UPS is expected to discharge/recharge the batteries for an average period of 5 minutes.

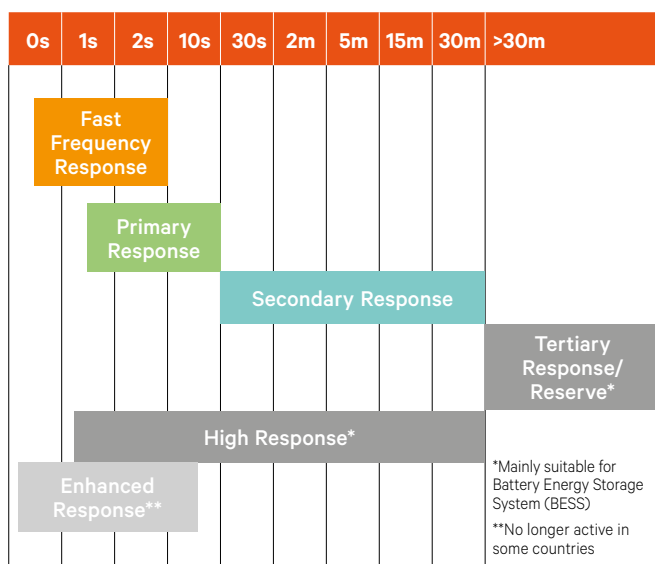


Figure 6. Example of Schematic of Frequency Response programs in UK

On the other hand, considerable electricity bill savings can be achieved through a proper demand management. In UK, the most relevant charges covering the cost of building and maintaining the national electricity transmission network are defined as Transmission Network Use of Systems (TNUoS). The National Grid determines TNUoS demand charges by using the **Triads**, defined as three half-hour settlement periods of highest demand on the UK electricity transmission system between November and February of each year, separated by at least ten full days.

Balancing services related with managing the user's peak level of demand to control TNUoS costs, targeting **Triads avoidance**, lead to the highest savings. The same applies to programs aimed at reducing Balancing Services Use of System (BSUoS), covering the Electricity System Operator day-to-day costs of keeping generation and supply in balance on a minute-by-minute basis.

2. Enabling Dynamic Grid Support with the Liebert® EXL S1 UPS

By enabling UPS grid services with elevated speed of response to frequency variations and other external commands, Vertiv allows data center owners to participate in specific demand and response programs (e.g. Fast Frequency Response and Peak Shaving).

The implementation of Grid Support features on **Liebert EXL S1** requires the integration of an external controller

whose function is to detect grid frequency variations (e.g. under frequency, 49.8 Hz, or over frequency, 50.2 Hz) and to inform the UPS by sending commands to adjust its input power accordingly. The UPS control system is designed to guarantee a quick reaction to these commands: the total response time between the frequency variation detection (the external controller to generate the command) and the moment the UPS reaches the specified power set point is less than 500 ms.

Dynamic grid support functionalities are compatible with both **VRLA** and **Lithium-Ion batteries**. LIB are the preferred solution for grid applications due to **higher number of cycles, quick charge and discharge**, possibility to be **monitored and controlled** through **BMS** by exchanging information with the UPS.

3. The Working Principle of a Grid-Interactive UPS

The UPS must be capable of adjusting its power demand on the utility to participate in ancillary services while keeping the **critical load** backed up with sufficient remaining battery runtime to allow for normal transfer to generators in the event of utility failure.

When a grid frequency variation is detected by the external controller, the UPS is commanded to follow this request for both positive and negative regulation by charging or discharging the batteries within their operational limits. The UPS controls the input power to achieve certain targets or services by working in different operating modes:

- **Standard UPS operation** (normal operation): With 100% input power from main utility grid through the rectifier, the UPS behaves as a standard double-conversion UPS - Figure 7.

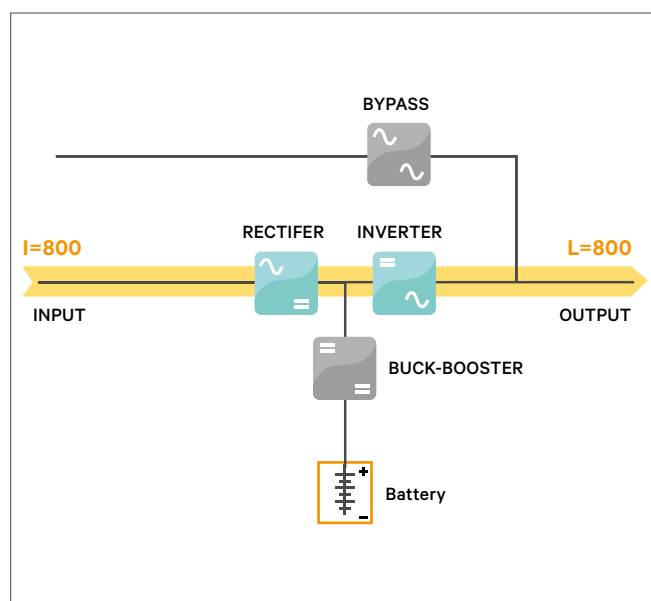


Figure 7. Standard UPS operation: considering 800 kW load, full power is coming from the utility grid

- **Discharge mode (Full Disconnection):** Full disconnection from the grid, 100% of the power to the load is coming from the battery after the command has been received from the external controller - Figure 8.

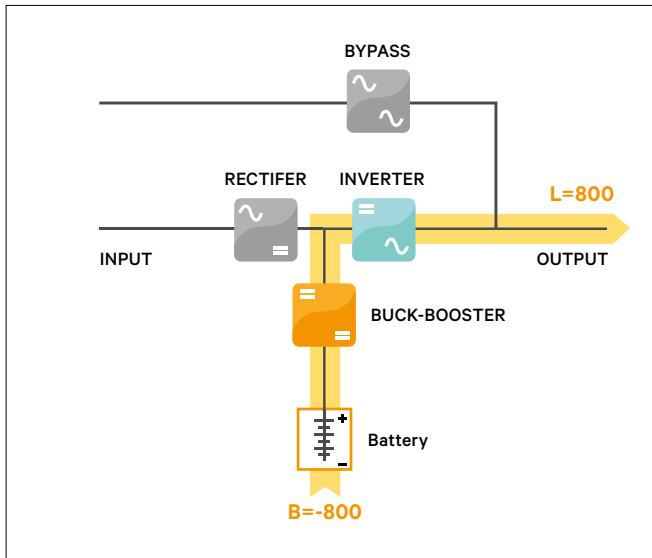


Figure 8. Full disconnection: considering 800 kW load, full power is coming from the batteries

- **Discharge mode (Partial disconnection):** The input power from the grid is adjusted and reduced following the external controller command. The remaining power for the load is coming from the batteries (25% in this case) - Figure 9.

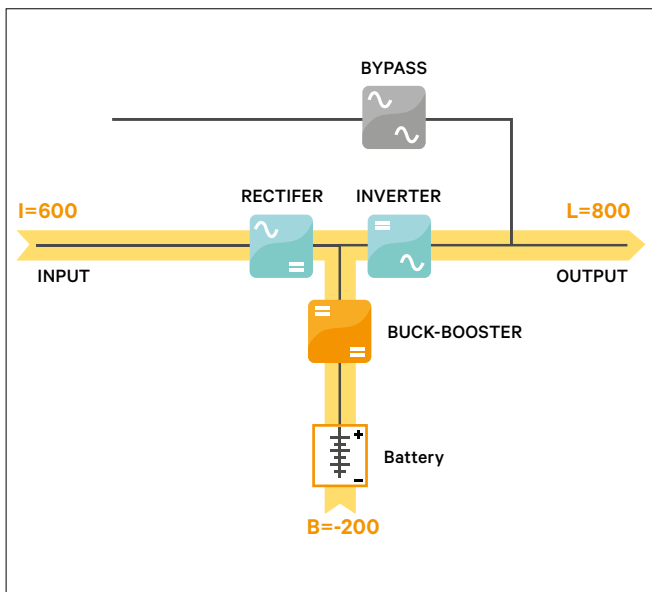


Figure 9. Partial Disconnection: considering 800 kW to the load, 600 kW are taken from utility grid, through the rectifier input, and 200 kW from the battery

- **Recharge mode:** When battery State of Charge (SOC) is below 100% (e.g. 80%), the utility starts to charge the batteries following an over frequency detection. Available maximum recharge power is typically 20-25% of maximum UPS capacity (limited by the battery recharge capacity and maximum input current) - Figure 10.

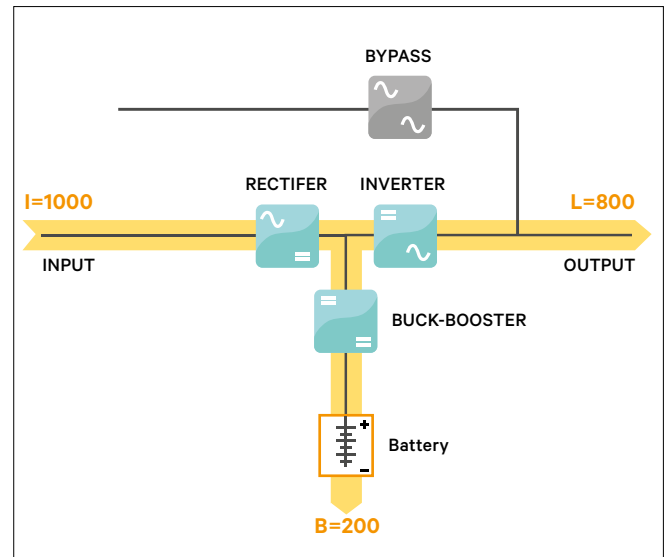


Figure 10. Recharge Mode: considering 800 kW to the load, 1000 kW are taken from utility grid, through the rectifier input, and 200 kW are used to charge the batteries

The UPS control is also able to manage energy **export** into the grid. When required, the grid interactive Liebert® EXL S1 will work as a **bi-directional power converter**, by discharging the batteries to inject power upstream the UPS. This feature is subject to characterization from each EMEA country based on the specific requirements to comply with local regulation and standards.

4. Grid Balancing Services Enabled By Liebert® EXL S1 UPS and Energy Storage

The Liebert EXL S1 UPS supports dynamic and static frequency regulation by modulating its response based on the frequency/voltage activation thresholds. The UPS also supports demand management when the commands to adjust the input power are related with demand control flexibility.

4.1 Static Frequency Regulation

Static regulation is performed via dry contact, with predefined fixed power response activated at a determined frequency deviation - Figure 11.

4.2 Dynamic Frequency Regulation

Dynamic regulation (Figure 12) is performed via Modbus with dynamic power response based on frequency deviation, such as:

- **Frequency regulation down** (over-frequency condition) via Modbus command to dynamically increase input power and battery charging.
- **Frequency regulation up** (under-frequency condition) via Modbus command to dynamically decrease input power and increase battery discharge.
- **Ramp power level up and down** (frequency regulation up and down).

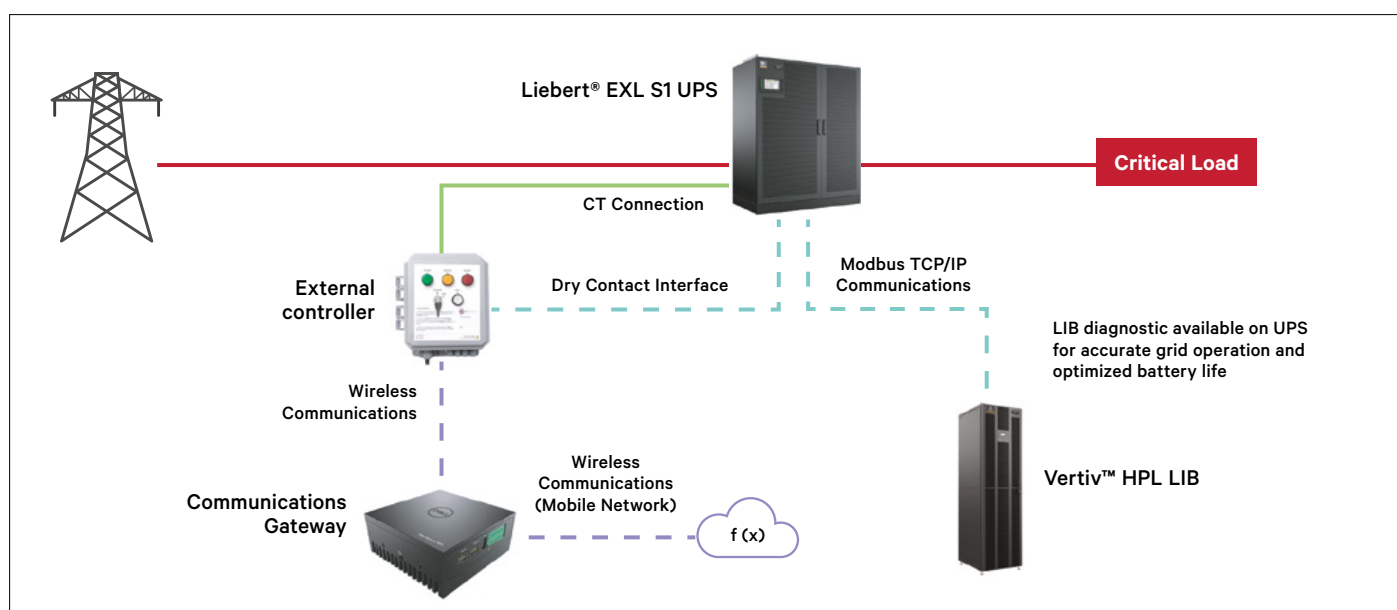


Figure 11. Schematic diagram for static frequency regulation with Vertiv HPL Lithium-ion battery storage

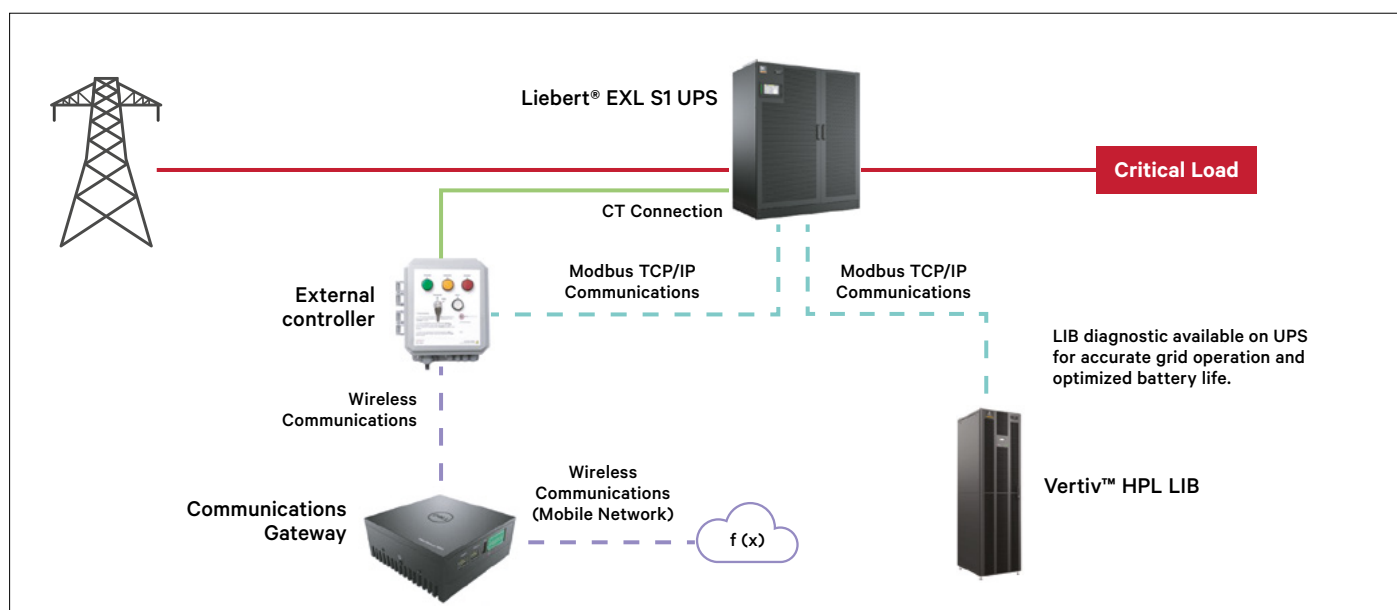


Figure 12. Schematic diagram for dynamic frequency regulation with Vertiv HPL Lithium-ion battery storage

5. Grid Interactive UPS: Key Advantages and Technical Features

5.1 Optimized for critical load

The primary UPS function is to **protect the critical load** and guarantee its runtime in every condition. This shall always be the highest priority, leading the control system to **exit/pause** the Dynamic Grid Support mode when the operating conditions are out of specification or increase risk.

5.2 Optimized for battery life

- Optimization features to **improve battery life** by controlling the main aging factors.
- Advanced diagnostics with **Vertiv™ HPL** lithium-ion battery storage also increase battery life.

5.3 Optimized for flexibility

- Specific parameters can be adjusted by the normal user via touchscreen or by the operator through the Vertiv service tool.
- The operator has the capability to **exit (stop)** or **pause** the Grid Services functionality under specific conditions, requiring a manual or automatic acknowledgment to restart it.
- The adjustable SOC range compensates for grid over/under-frequency. This has three settings and can be adjusted through the machine interface (Figure 13).

SOC RANGE	Maximum Soc threshold for grid services (adjustable via UPS setting)	100%		Available battery capacity to store additional energy (over-frequency)
		80%		
	Real time battery SOC	65%	A	Energy stored for grid services (under-frequency and over-frequency)
	50%	B		
	Minimum Soc threshold for grid services (adjustable via UPS setting)	0%		Energy stored for critical load (grid services disabled)

Figure 13. Adjustable State of Charge Range for Grid Services and Critical Load

6. Trading Business Models to Access Grid Balancing Services

In typical data center applications, backup batteries **are not used for most of the time**, being required only in case of utility failure. This is the reason why many operators have already offered their back-up energy storages and UPS for the ancillary services market as primary or secondary reserves. Stored battery power can in fact support generating money for the times where this capacity is not needed without compromising the IT load availability.

The trading business model proposed to contract balancing services are:

- **Direct:** Data center owners invest in the assets, bid directly to the grid system operator, and benefit entirely from the revenues generated by grid services, while introducing potential risks, complexities and contractual obligations that may require different expertise.
- **Indirect:** The aggregator or energy service provider fully or partially finances the investment, signs the contracts with the utilities to participate in grid balancing programs and receives the related revenues.
- **Hybrid:** Joint approach or partnership between a vendor and an aggregator/energy service provider to grant market access and participation in grid services for the end user. The vendor supplies the asset while the aggregator supports the end user in defining market rules and training them to participate in the balancing services.

There are pros and cons in each of the proposed models. The key variables to consider are the scale of the company and the size of the potential asset, along with risks and costs related to the initial capital investments. The minimum size of the asset to be eligible for Grid Services vary by the type of service, e.g. frequency response services require from 1MW to 50MW.

The **hybrid approach** may be the most appealing choice for an operator entering the market given the complexity of the interactions between all the parties involved.

Conclusion

Liebert® EXL S1 with Dynamic Grid Support allows energy-intensive industries **to utilize UPS systems in a proactive way**. As intermittent renewables continue to challenge conventional electric power generation, new energy storage services are required to help meet sustainability goals, generate revenue and reduce energy bills. Ultimately, this will alleviate grid infrastructure constraints and increase use of renewable power sources.

In this value network, Vertiv can support operators in generating earnings and reducing costs by means of **smart assets** such as the UPS with grid support functionalities. Vertiv can supply the full integrated solution (Grid Interactive UPS with external controller and energy storage) both to the **end user** and the **aggregator/energy service provider**.

A UPS with grid support is an optimal solution to provide Grid Balancing Services, especially in data centers where battery storage assets are already present and not utilized for most of the time. This can be achieved through Liebert EXL S1 with the new Dynamic Grid Support feature while ensuring the main UPS functionality of critical load protection.



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