

Energy Storage Arbitrage Models and Applicable Scenarios

When it comes to energy storage, many people first think of backup power. However, its value extends far beyond that; it is a powerful commercial asset and strategic tool that generates profit through energy arbitrage. Understanding these arbitrage models and their applications is therefore crucial for capturing key opportunities in the energy transition.

Energy Arbitrage

Energy arbitrage is the most direct way for energy storage to generate profits by capitalizing on electricity price spreads.

1. Time-of-Use

The energy storage system charges by purchasing low-cost electricity from the grid during off-peak periods. It subsequently discharges the stored energy to the user's load or back to the grid during peak or super-peak periods to realize a profit.

This model is predominantly adopted by high-energy consumption industries, such as industrial parks, large factories, and data centers, especially in regions with clear Time-of-Use (TOU) tariff policies and significant differential pricing between peak and off-peak periods.





ATESS HPS150+BR157 battery bank installed for a glass factory in Romania to reduce energy cost

2. Spot Market

This approach is the primary revenue source for merchant storage projects. These are typically structured as independent battery energy storage systems (BESS) that are grid-connected and operate in regions with deregulated electricity spot markets. Instead of relying on fixed TOU tariffs, they engage directly in the wholesale market, leveraging sophisticated forecasting algorithms to buy low and sell high by capitalizing on real-time price volatility.



3. Renewable + Storage Arbitrage

With the widespread adoption of electricity spot markets, the participation of "renewable energy + energy storage" in market trading is gradually becoming mainstream. This strategy allows storage systems to charge when an oversupply of renewable generation drives electricity prices down to low or even negative levels, or during periods of curtailment (e.g., wind curtailment). The energy is then discharged later when the grid requires it or prices are higher.

Applicable Scenarios:

- **Centralized Wind and Solar Farms:** Particularly in regions with limited grid absorption capacity and severe curtailment issues, energy storage not only fulfills mandatory allocation policies but also transforms curtailed power into income and helps capitalize on spot price volatility.
- **Distributed PV Owners:** For owners of distributed solar systems, energy storage can significantly increase the self-consumption rate of solar power, reduce reverse power flow to the grid, and effectively manage time-of-use electricity price fluctuations.

System Service Arbitrage

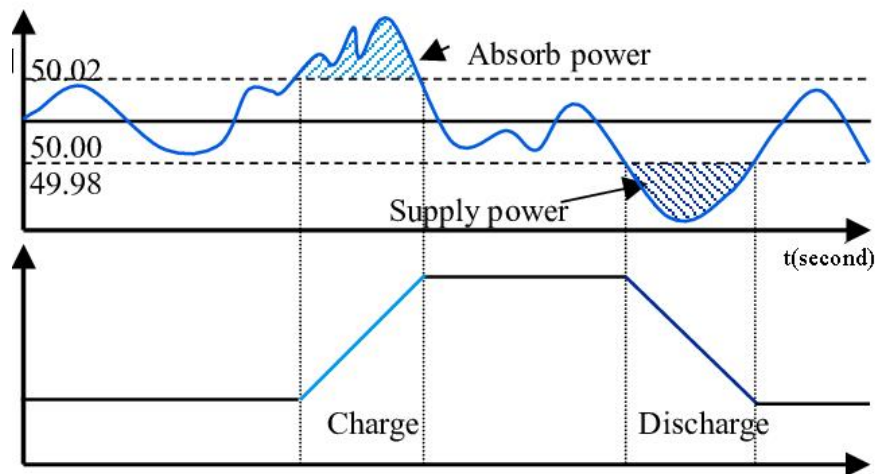
Energy storage also generates value by delivering stability and reliability services to the grid, earning service revenue.



1. Ancillary Service

Key Service Types:

- **Frequency Regulation:** Responds to grid frequency fluctuations within milliseconds through precise charging/discharging. Compensation is based on regulation mileage, with higher performance yielding greater revenue.



- **Reserve Capacity:** Provides standby power for sudden grid outages, earning capacity fees even when not dispatched.
- **Black start:** When a large-scale power outage occurs in the power system without external power support, the energy storage system is used as a self starting power source to quickly establish initial voltage and frequency, drive other generator units to restart, and ultimately achieve the recovery of the entire power grid.

Applicable Scenarios:

- Ideal for grid-side and independent energy storage projects pursuing high returns and revenue diversification.
- Co-locating with thermal power plants in thermal-storage frequency regulation systems can multiply traditional plant earnings while improving grid performance.

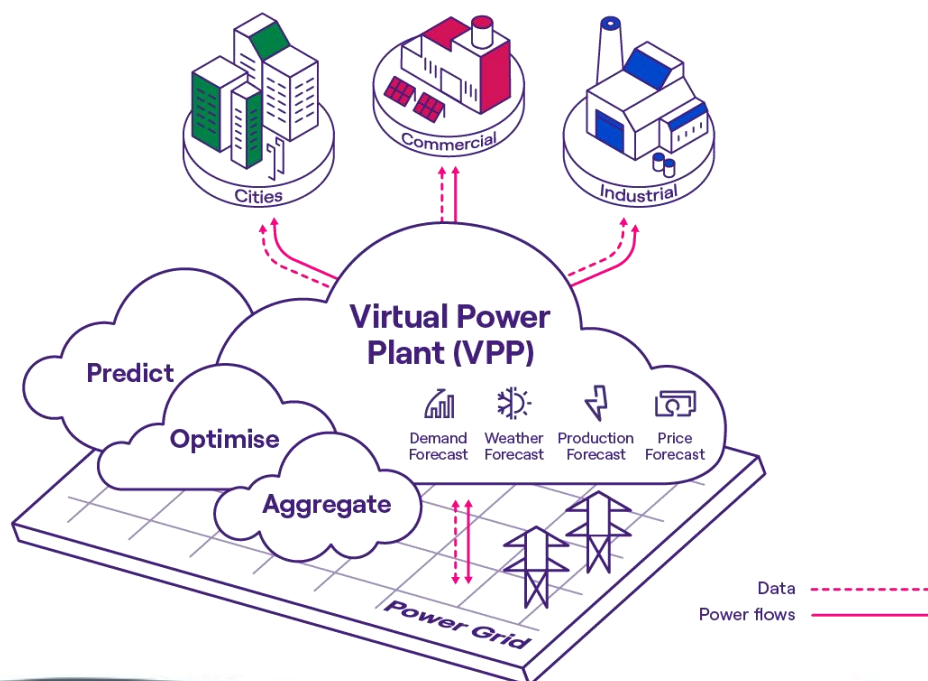


- Operators with strong market trading and forecasting capabilities can maximize returns in grids with high ancillary service demand, such as the North China and East China Grids.
- The ATESS PCS1000-1500HV series high voltage inverter is perfect for such application. With high conversion efficiency, rapid response capabilities, and rigorous grid compliance, it efficiently stabilizes grid frequency, ensures reliable reserve power supply, and facilitates the smooth integration of renewable energy.

2. Virtual Power Plant(VPP)

A VPP is a technological and operational platform that aggregates a large number of distributed energy resources, including behind-the-meter energy storage, electric vehicles, and flexible loads, to participate in electricity market transactions as a single, unified entity.

Through a VPP, these assets can simultaneously participate in multiple value streams, such as energy arbitrage, ancillary services, and demand response, thereby achieving revenue stacking and maximizing their total returns.



Other Core Value Models

Although these models do not directly derive from market transaction spreads, they are an important component of energy storage's economic viability.

1. Capacity Compensation/Leasing

This refers to a payment mechanism for providing reliable power capacity to the grid. In other words, energy storage systems earn revenue (capacity payments or leasing fees) by being on standby to deliver electricity during periods of high demand or system stress. It's applicable in regions with established capacity market mechanisms (e.g., PJM in the U.S., the UK) or those mandating firm capacity for renewable energy projects.

2. Asset and Cost Optimization

(1) Transmission and Distribution Upgrade Deferral

When regional load growth approaches the capacity limits of existing equipment, the traditional solution is to invest in building or upgrading power lines or substations. As a non-wires alternative for grid companies, energy storage systems can discharge during peak hours to reduce peak load, thereby alleviating stress on grid assets and deferring or even avoiding costly capital investments.

Applicable Scenarios:

- Urban power grids with rapid load growth, high land costs, and difficult expansion conditions.
- Areas with poor power quality at the grid edge or those experiencing seasonal overloads.



(2) Demand Charge Management for C&I Customers

This application targets commercial and industrial (C&I) customers under a two-part tariff structure. In such markets, a significant portion of their electricity bill comes from a demand charge, which is based on their highest power draw (peak demand) during the billing period. Energy storage systems can discharge during short periods of peak consumption to shave this peak demand, directly reducing this substantial portion of the electricity bill and creating a strong economic driver for behind-the-meter storage projects.



ATESS PCS250+BR200 energy storage system installed for a mechanical processing factory in Italy, saving 8,000+Euro per month for the factory.

Conclusion

In summary, the value of energy storage is multifaceted, generating economic returns through multiple avenues. Understanding how these models interact and identifying the scenarios where they best apply are key to unlocking the full potential of energy storage as a cornerstone of a flexible, resilient, and decarbonized power system.

