

INTRODUCING

GridStore

GridStore

Integral Analytics (IA) appraisal software values grid-scale battery technologies

Founded on the same highly detailed financial engineering methods used to value complex energy assets and traded commodity contracts, the IA grid-scale battery valuation software is able to deliver the most accurate financial pro-forma estimates available in the industry today. Without these detailed financial valuations, other methods risk under-valuing, or incorrectly valuing, many types of storage applications. The IA methodology uses many of the same ideas deployed in the natural gas industry to value gas storage assets, but with the additional emphases on weather related value-at-risk over the life of the battery asset. The IA model simulates the behavior of a rational operator when faced with market prices and technology constraints. Both complex battery ramp rates and depth-of-discharge degradation constraints are modeled.

Price Spread-Option Forecasts Using Causal Simulation of Weather Risk

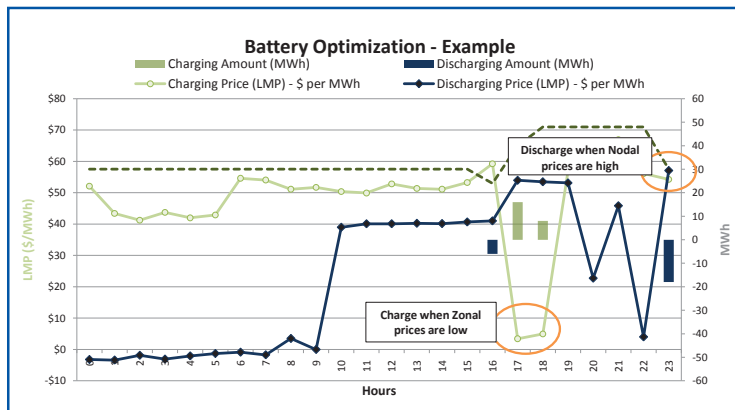
- Using the IA proprietary casual simulation, forecasting and valuation systems, complex price scenarios are simulated over multiple years of historic weather data to assure all possible conditions, extreme or mild, are included in the valuation process.
- An efficient and accurate price spread-option approach is used by many utilities for traditional storage applications and is used in battery valuation applications.
- Our spread-option valuation of storage assets is a well understood and documented method that uses stochastic calculus to measure the present and future cash flow probabilities.
- Accurately characterizing the extreme price spreads is critical in the valuation. These price spreads occur in the tails of the probability distribution, not the averages, so detail matters.

Optimization Consistent with Battery Technologies

- The IA modeling and valuation framework forecasts and simulates the behavior of rational dispatch decisions, when faced with market prices and technology constraints.

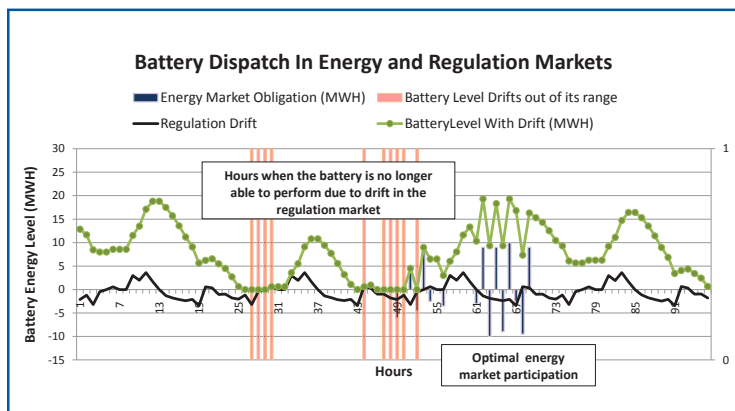
- Both complex battery ramp rates and depth-of-discharge degradation constraints are modeled.
- The IA valuation approach considers several benefits of grid-scale storage, some of which can be monetized today. These include:
 - › The ability to shift energy from off-peak to peak hours via price arbitrage
 - › The ability to provide quick ancillary services for the frequency regulation market
 - › The ability to firm renewable resources
 - › The ability to absorb unused wind generation during periods of oversupply

Exhibit 1 – Optimal Battery Dispatch



The idea of energy market arbitrage is always a good starting point for battery valuation. However, using a revenue optimization framework subject to battery ramp rate and degradation cost constraints, we often find that the best solution favors short price spikes and quick charging cycles. **Exhibit 1** shows a one day snapshot of how a rational operator would cycle the battery when faced with a set of prices and known degradation costs. In this optimal solution, the degradation costs are minimized by the quick cycling charging and discharging strategy.

Exhibit 2 – Battery Participation in the Energy and Regulation Markets



IA further considers regional market characteristics that may impact battery value. **Exhibit 2** shows an illustrative drift toward regulation up. The exhibit further demonstrates how the battery optimally interacts with the energy market and regulation markets. The relationship largely depends on the magnitude of the price spreads and battery cycling degradation costs. For this battery, short cycles in the energy market are preferred, but only during those times when the energy price spreads are large enough to generate more revenue than the regulation market less degradation costs.

For more information contact:

Ken Skinner
 kenneth.skinner@integralanalytics.com
 513-762-7621



Integral Analytics, Inc.
 312 Walnut Street, Suite 1600
 Cincinnati, OH 45202