

Positive Balancing

Impact on Profitability of Utility-Scale Batteries

Abstract: Positive Balancing is a new battery management technology that eliminates out-of-balance conditions and captures cell impedance data in real-time. This paper analyzes the impact Positive Balancing has on profitability and cost of operations of a utility-scale battery.

The battery used in this analysis is 200MW/800MWh LFP. Details of the battery and the cost model are on the last two pages of this paper.

Summary of Results:

Category	Description of Savings	Amount of Savings
CapEx: Initial cost of battery	Reduce the amount that the battery must be oversized	5% to 33% reduction in initial cost of battery Savings of \$2.75M to \$18M
Decline in battery capacity	Capacity decline is reduced to absolute minimum. Lost revenue due to decline in battery capacity is minimized.	Savings of \$2M to \$8M per year
Balancing	Eliminate need to take strings offline for balancing	Savings of ~\$1M per year
Augmentation	Reduce or eliminate need for augmentation	Savings of \$2M to \$10M
Fines or penalties for derating	Reduce or eliminate fines or penalties for derating	Varies widely across the industry
Battery life	Extend battery life by 20% to 40%	Increase ROI by 5% to 10%
Cell impedance data	Early warning of cells going bad. Allows preventive maintenance before battery failure or battery fire.	Varies widely What is the value of preventing a battery fire?

Cost of out-of-balance conditions in utility-scale batteries

- Out-of-balance is the largest cause of loss of revenue in utility-scale batteries.¹
- Batteries can lose between 10% and 20% of available capacity due to out-of-balance.²
- In most utility-scale batteries, modules or strings need to be taken offline for balancing. When those modules/strings are offline, there is 100% loss of revenue from them.³
- Modules or strings can be offline for hours or days while rebalancing.⁴
- Loss of revenue due to out-of-balance batteries can cost between \$10k to \$40k/MW/year.⁵
 - For example, loss of revenue due to out-of-balance on a 200MW battery can be between \$2M/year and \$8M/year
- Three ways the industry currently addresses the out-of-balance problem:
 1. Oversize the battery by anywhere from 5% to 33%.⁶
 - On a battery with nominal capacity of 800MWh, this can represent additional up-front CapEx of \$2.75M to \$18M.⁷
 2. Augment the battery by adding modules as the battery ages
 - Augmentation might be required several times over the life of the battery
 3. Negotiate with the utility to accept derating at a faster rate
 - This reduces the revenue stream over the life of the battery. Batteries that derate faster generate less revenue.
 - If battery capacity declines below the agreed-upon rate of derating, the battery operator must pay penalties to the utility.

¹ Source: TWAICE webinar on cost of out-of-balance conditions in BESS

² Source: TWAICE and Modo Energy

³ Source: TWAICE

⁴ Source: Modo Energy

⁵ Source: TWAICE slide deck

⁶ Source: TWAICE

⁷ Source: The battery model on the last two pages of this document

Summary of cost of out-of-balance to BESS operators:

1. Oversize the battery, which increases CapEx
2. Loss of revenue when modules or strings need to be taken offline for balancing
3. Reduced revenue due to lower capacity
4. Augmentation – hard costs for installing additional battery modules
5. Reduced revenue and/or fines associated with derating

How Positive Balancing Can Help

- Minimize or eliminate all of these areas of cost.
- Positive Balancing (recommended for utility-scale batteries) adds between 1.0% and 1.25% to the total cost of the battery. This is about \$625,000 for an 800MWh battery.⁸
- Potential savings in an 800MWh battery:
 - \$2.75M to \$18M reduction in initial CapEx
 - The amount of oversize can be reduced significantly
 - \$2M to \$8M per year for every year of operation of the battery
 - Completely eliminate loss of revenue caused by out-of-balance conditions
 - \$2M to \$10M
 - Significantly reduce or eliminate need for augmentation
 - An additional \$1M per year
 - Modules or strings never need to be taken offline for balancing
 - Minimize or eliminate costs and penalties associated with derating

⁸ See battery cost model on the last two pages of this document.



Additional Benefits

Extend Battery Life

Out-of-balance conditions cause batteries to reach end-of-life prematurely. By eliminating out-of-balance conditions, Positive Balancing can extend battery life by 20% to 40%. A battery that would normally need to be retired at 10 years could have a 12-to-14-year life which can increase ROI by 5% to 10%.

Cell Impedance Data: Early Warning of Cells Going Bad

In addition to eliminating out-of-balance conditions, our technology can provide real-time data on impedance of every cell in the series stack.

Impedance data can provide early warning of cells that are going bad. This allows you to schedule preventive maintenance at a time that will minimize loss of revenue. More importantly, the battery can be repaired before critical or catastrophic failure occurs. Cost of critical/catastrophic failures varies widely, ranging from several million dollars for battery failures to hundreds of millions of dollars for battery fires that spread and cause damage to property surrounding the battery.

What is Positive Balancing?

Positive Balancing is the latest balancing technology from True Balancing LLC. It offers fast balancing, high efficiency and low cost – and provides real-time data on cell impedance. Positive Balancing can completely eliminate out-of-balance conditions in any battery regardless of cell chemistry, size of battery, age of battery and use environment.

One example of the unique capabilities of all of our balancing technologies: They can perfectly balance any LFP battery at any SOC. If you have been struggling with out-of-balance LFP batteries, we invite you to contact us and learn more about our balancing technologies.

Reference battery for analyzing added-value of Positive Balancing to BESS

Table 1: Baseline Parameters

Item #	Baseline Parameters	Value	Units	Comments
1	Nominal power:	200	MW	Assume that these are the customer's requirements for total battery power and back-up duration
2	Back-up duration at full power:	4	hours	
3	Cell chemistry:	LFP	n/a	LFP is the most common battery chemistry for large stationary BESS
4	Cost of cells per kWh:	\$50	\$	This is lowest available price from the largest Chinese cell manufacturers. This price does not include tariffs. Source: Volta Foundation 2024 Battery Report
5	Additional cost for "everything else":	38%	Percent	Source: Volta Foundation 2024 Battery Report; ultimate source is BloombergNEF
6	Nominal cell voltage:	3.2	V	
7	Pack voltage:	1,600	V	I chose 1600V because it's a reasonable voltage for grid connection, and with pack voltage of 1600V most of the derived values in Table 2 are integers
8	Individual cell capacity:	300	Ah	We assume 300Ah prismatic cells
9	Cells in series per module:	50	Cells	Each module has a 50S1P architecture
10	Cells in parallel per module:	1	Cells	
11	Number of channels per Positive Balancing board	25	Channels	"Channels" refers to balancing channel. The complete system will have one balancing channel for each cell in series in each string.
12	Maximum balancing current:	15	A	15A balancing current is ~0.05C for 300Ah modules. This should be sufficient to keep the battery balanced for its entire life if Positive Balancing is OEM equipment.
13	Cost per channel of Positive Balancing board	\$0.75	\$	This cost estimate assumes high-volume mass-production for a 15A Positive Balancing system

Table 2: Derived Parameters

Item #	Derived Parameters	Value	Units	Comments
1	Nominal energy:	800	MWh	200MW power x 4 hours of back-up
2	Total cells in series:	500	Cells	Pack voltage divided by cell voltage: 1600V ÷ 3.2V
3	Number of cells per module:	50	Cells	50S/1P architecture
4	Volts per module:	160	V	3.2V/cell x 50 cells in series
5	Number of modules in series:	10	Modules	Pack voltage divided by module voltage: 1600V ÷ 160V
6	Capacity of each module:	300	Ah	Cell capacity times number of cells in parallel: 300Ah x 1
7	Nominal energy of each module:	48,000.00	Wh	Module voltage x Ah capacity of each module: 160V x 300Ah
8	Minimum number of modules:	16,666.67	Modules	Nominal energy of battery ÷ nominal energy of each module: 2000MWh ÷ 48kWh
9	Number of modules to make complete strings of 10 in series	16,670	Modules	Rounded up to nearest 10
10	Nominal energy of battery as configured:	800.16	MWh	Nominal energy of each module x number of modules: 48kWh x 16,670 modules
11	Cost of bare battery:	\$40,008,000	\$	Nominal energy of battery x cost per kWh: 800.16MWh x \$50/kWh
12	Cost of "everything else":	\$15,203,040	\$	Additional cost of "everything else" is 35% of cost of bare battery (from Table 1, Item 5))
13	Total battery cost:	\$55,211,040	\$	Sum of bare battery plus "everything else"
14	How much battery is oversized:	0.02%	Percent	Battery as configured is oversized by 0.022% over customer spec See note 1
15	Number of Positive Balancing boards/module:	2	Boards	25 channels per board; 50 cells in series per module.
16	Total number of 25-channel Positive Balancing boards:	33,340	Boards	2 boards/module x 16,670 modules
17	Total number of channels:	833,500	Channels	25 channels per board x 33,340 boards
18	Cost of balancing system:	\$625,125	\$	\$0.75 per channel x 833,500 channels
19	Cost of balancing system as % of battery cost:	1.13%	Percent	

Note 1: For purpose of this value analysis, we start with the battery sized as closely as possible to the nominal requirement.

Cost to oversize the battery by 5%: \$2,760,552

Cost to oversize the battery by 33%: \$18,219,643