Benefits of True Balancing

This document describes 24 distinct benefits that True Balancing brings to battery systems.

No other battery management technology that we know of can provide such a broad range of benefits.

This document has short, non-technical explanations of each benefit.

The next page has a table of contents. You can click on any line in the table of contents to link directly to that page. This lets you jump quickly to any item that looks interesting to you.

If you would like to learn more about True Balancing, please contact us at:

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1. Maximize energy that is stored in the battery during charge cycles

   If you aren't using True Balancing, your batteries aren't getting fully charged. It's that simple.

2. Maximize energy that the battery can deliver during discharge cycles

   Our tests with NMC and LFP cells show that True Balancing increases battery capacity by 1% to 3% (with cells that are new and are very closely matched) and by 10% to 15% (with cells that are aged and less closely matched). How much value would that add to your batteries?

3. Maximize the life of the battery

   We analyzed batteries from six tier-2 battery manufacturers and found that True Balancing could double their life. True Balancing may not be able to double the life of tier-1 batteries, but it will give every battery the maximum possible life.

Explanations of these three benefits are fairly technical.

These benefits are described in more detail in papers that are available at:

www.truebalancing.com

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4. Reduce battery cost by 5% to 10%

   True Balancing reduces battery cost in two ways.

   First, True Balancing puts more energy into the battery during charge cycles and gets more energy out of the battery during discharge cycles. This effectively makes your battery 5% to 10% bigger just by making a minor, low-cost change to the BMS electronics. Your cost per unit of energy will drop.

   Another way True Balancing reduces battery cost is by allowing you to buy lower tier batteries and enjoy the performance of higher tier batteries.

   A lithium-ion battery scientist who saw a demonstration of True Balancing told us that by switching to True Balancing, tier-2 batteries would perform similar to tier-1 batteries; tier-3 batteries would perform similar to tier-2; etc. This corroborates what we have seen in our tests of True Balancing systems.

   The battery is far and away the most expensive component in any EV. Switching to True Balancing is a modest change in the BMS electronics that can reduce your battery cost by 5% or 10%. That's a savings of $500 to $1000 on an EV battery pack that costs $10,000.

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5. The power of CCCV charging

   CCCV charging is the gold standard for battery charging. Applying a CCCV charge cycle to an individual cell brings the cell up to full charge voltage during the constant current phase, and then up to 100% SOC during the constant voltage phase.

   In an EV battery, charging each cell in the series stack with a separate CCCV charger would require connecting an isolated CCCV charging power supply to each cell in the series stack – and that would require about 100 isolated chargers. This is prohibitively expensive.

   True Balancing is the exact equivalent to charging with a series of isolated CCCV chargers but at much lower cost, using simple, low-cost electronics on a single PCB.

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6. True Balancing is flexible

   True Balancing isn't a one-size-fits-all, cookie-cutter system. *True Balancing offers a range of design options that no other balancing system can match.*

   True Balancing can work with any battery chemistry, any number of cells in series, any battery architecture, and with batteries of any capacity. True Balancing systems can work in any application and environment: Automotive, industrial, energy storage, marine, etc.

   Maximum balancing current can be any level desired from 1A to 100A, allowing you to optimize price/performance trade-offs for the requirements and use patterns of any vehicle.

   True Balancing can provide software-based features to optimize vehicle performance, minimize stress on the cells, maximize battery life, monitor the health of the cells as they age, and provide early warning of potential cell failures.

   All charging and balancing parameters are set in software and can be changed in real-time to adjust the performance of the battery to address the specific requirements of changing circumstances.

   You can design True Balancing systems that are optimized for daily commuting, for commercial delivery vans, for long distance cargo hauling, or for any other battery use case you can imagine.

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7. Measure cell impedance in real-time in the vehicle

Every lithium-ion cell undergoes rigorous testing and characterization at the end of the manufacturing process. Two key data points in the testing process are DC resistance and AC impedance (typically measured at 1kHz). Impedance measurements provide valuable information on the overall condition and health of the cell.

Once cells are assembled into a battery and installed in the end product (such as an EV), it becomes difficult or impossible to obtain measurements of cell impedance.

True Balancing changes that.

True Balancing can monitor impedance on a cell-by-cell basis. The components that measure impedance are an integral part of True Balancing, so measurement of cell impedance adds zero cost to a True Balancing system.

True Balancing can measure DC resistance; AC impedance at selectable frequencies up to 10kHz; static impedance (V/I); and dynamic impedance (dV/dI). True Balancing can measure impedance while the battery is in the vehicle – during charging or discharging, or while the vehicle is idle.

This is one of the most significant breakthroughs of True Balancing. Cell impedance can now be measured, logged, and transmitted to the battery manufacturer and/or vehicle manufacturer.

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8. Early detection of cells that are starting to fail

   Changing impedance is one of the most reliable indicators of the health of cells. If the impedance of one cell is rising faster than the rest of the cells in the pack, it's an indication that the cell with rapidly rising impedance could be going bad. True Balancing can detect this very early.

   If True Balancing detects impedance changes that indicate a possible problem, it can send a message to the vehicle management system. The system UI can notify the driver that the vehicle should be inspected and serviced.

   Without True Balancing, rapidly rising cell impedance could result in battery failure.

   With True Balancing, this condition can be detected early and fixed with low-cost preventive maintenance.

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9. Faster, easier, lower-cost battery repair

   Maintenance and repair of EV batteries is extraordinarily inefficient and expensive – and that's because of limitations in present-day balancing systems.

   If you detect that a specific cell has gone bad, the logical repair would be to replace the module that has the bad cell. But there is a problem with that.

   When a battery module needs to be replaced, the vehicle has probably been on the road for some time. The cells and modules have drifted into variable and unknown conditions. It is nearly impossible to install a replacement module that is closely matched to all of the other modules in the battery. If the replacement module differs even modestly from the other modules, passive balancing systems will struggle to keep the battery balanced. The battery will get out of balance at an accelerating rate and will die a premature death.

   True Balancing can compensate for variations in characteristics that are introduced by the replacement module. The battery will be much better balanced and battery life will be much longer than with a passive balancing system.

   Additionally, True Balancing can tell the service technician the exact module that needs to be replaced and can inform the technician of the condition of all of the other modules.

   With True Balancing, battery repairs are faster, easier, lower cost and longer lasting.

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10. Reduce charging anxiety

    This benefit is particularly applicable to EV owners.

    Today's EVs have on-board notifications that advise drivers on when they can or can't charge the battery, and how quickly or how much they should charge it. There are two reasons for this: Treat the cells gently to slow down the rate at which they degrade, and try to prevent the cells from getting out of balance.

    True Balancing can completely eliminate out-of-balance conditions in any battery, so warnings and restrictions related to battery charging can be relaxed.

    With True Balancing the user can charge their EV whenever they want to, wherever they want to, and can charge the battery as much as they want to. Charging anxiety is reduced.

    Slower charge rates are always easier on the cells than fast charge rates. That's immutable. But with True Balancing the battery can recover quickly and completely from out-of-balance conditions that occur after repeated charge/discharge cycles at varying rates of charge and varying charge endpoints.

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11. Better management of fast-charge cycles

    Charging a battery at a fast charging station is like filling a series of water balloons with a firehose. Energy is delivered to the cells at such a high rate that it's impossible for passive balancing systems to keep up. The cells get pushed into unknown states at uncontrolled rates. A few fast charge cycles can put the battery into an extremely out of balanced state that passive balancing systems will struggle to correct.

    True Balancing mitigates the problems associated with fast charge cycles. It does this in two ways.

    First: True Balancing has balancing currents that are 10x to 30x higher than passive balancing currents, so the battery will not be pushed so far out of balance during fast charge cycles.

    Second: If fast charge cycles push the cells out of balance, True Balancing will bring the battery back into perfect balance and up to 100% SOC on the very next full charge cycle. True Balancing can do this very quickly and with complete reliability (as long as no cells get destroyed during the fast charge cycle).

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12. Automatically compensate for variations in cell characteristics

    Batteries are assembled by the battery manufacturer using brand new cells under tightly controlled conditions. At time of assembly, cell characteristics can be matched as closely as you want (or as much as your battery budget allows).

    After the battery is put to use in the real world (for example, an average person driving an EV) the battery is subjected to uncontrolled conditions. The use environment is uncontrolled. Driving patterns are uncontrolled. Charging patterns are uncontrolled. Cell characteristics will start drifting – that's unavoidable.

    As cell characteristics drift, the battery starts to get out of balance. Eventually the passive balancing system can no longer compensate for the condition of the cells. At that point the battery gets further out of balance with every charge/discharge cycle.

    True Balancing completely eliminates this problem. *True Balancing can bring the battery to a perfectly balanced state and bring every cell to 100% SOC at the end of every full charge cycle, regardless of variations in cell characteristics.*

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13. Automatically compensate for cell failures in parallel strings

    EV batteries are typically comprised of strings of cells connected in parallel to provide the needed battery capacity. Then parallel strings are connected in series to provide the needed voltage.

    For purposes of charging and balancing, strings of cells connected in parallel are essentially equivalent to one big cell.

    On occasion, individual cells in parallel strings can fail. When this happens, there is a quantum drop in the capacity of that parallel string. Passive balancing systems are not good at handling quantum drops in cell capacity.

    True Balancing can charge and balance with 100% reliability regardless of failures of individual cells in parallel strings.

    This is another feature that sets True Balancing apart from all other balancing technologies, and it solves one of the most intractable problems in batteries that have strings of cells connected in parallel.

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14. Automatically compensate for temperature variations in the cells

    All battery packs experience temperature gradients across the cells. Battery system engineers must design thermal management systems that prevent the cells from rising above a threshold temperature and limit the temperature differential across the cells.

    Temperature differentials create differences in cell capacities and these differences in cell capacities can render existing balancing systems completely ineffective. To prevent this from happening, the thermal management system must maintain the cells in a narrow temperature range. This drives up the cost and complexity of the thermal management system.

    True Balancing can bring every cell up to 100% SOC regardless of temperature gradients in the battery pack.

    The amount of energy that a cell can hold is affected by temperature. That's a law of physics that can't be changed. But True Balancing can charge each cell up to the maximum amount of energy that it can safely hold regardless of cell temperature. So battery capacity is always maximized regardless of the thermal state of the battery.

    In layman's terms, with True Balancing your batteries will perform well from winter in Wisconsin to summer in Sarasota.

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15. More accurate estimate of battery capacity

    At the end of each charge cycle, True Balancing brings every cell in the battery up to FCV and then to 100% SOC. This is a well defined endpoint of charging, which allows an accurate estimate of the amount of energy stored in the battery.

    In contrast, charge cycles with passive balancing systems tend to have “soft” endpoints. The cells are not in a known and well-defined state at the end of the charge cycle and the state of the battery at the end of the charge cycle is different every time. Typically, every cell is at a different SOC and the voltages of the cells in the series can also vary.

    This is an unavoidable shortcoming of existing batteries which limits the accuracy of estimates of available battery capacity. With well-defined charging endpoints and ability to calculate cell impedance,True Balancing can provide more accurate estimates of SOC.

    Accurate estimates of battery capacity can be of critical importance, particularly with respect to EV driving range.

    If you have been driving the car for a few hours, True Balancing can provide a more accurate estimate of whether you can continue directly to your destination or must stop to recharge en route.

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16. Reduced load on the electric grid

    This is a relatively minor advantage of True Balancing.

    Passive balancing systems are extremely inefficient. When they are operating, 100% of the balancing current is drained from the cells and turned into heat. Honestly speaking, this is 100% inefficiency.

    When True Balancing is charging the battery, almost all of the energy that enters the battery stays in the battery. As the battery approaches full charge, energy from the charging source is diverted around the fully charged cells and brought to cells that are still approaching full charge. This is an extremely energy efficient way to charge and balance a battery.

    The energy savings in one vehicle on one charge cycle may not be big. *But when you multiply this energy savings across millions of vehicles that are being charged on a daily basis, the amount of saved energy can become significant.*

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17. True Balancing is cool

    True Balancing generates much less heat than existing balancing systems, because it moves energy very efficiently from cell to cell. *True Balancing generates less heat than every other balancing technology that we are aware of.* Less heat means less thermal stress on the battery and the system electronics.

18. Lower scrap rate for battery manufacturers

    We were demonstrating True Balancing to an executive from a major Asian battery manufacturer. About halfway through the demonstration, he stopped us and said, “If I have this technology, my scrap rate would be cut in half.” About half of the scrapped cells from his production process are completely unusable. But he said that the other half of his scrapped cells fall just a bit outside the performance standards that his customers will accept. These cells could be used in a battery with True Balancing. True Balancing would compensate for the conditions of the marginal cells so that the performance of the entire battery would be acceptable to customers who buy tier-2 or tier-3 batteries.

    True Balancing can increase production yields and lower production costs for battery manufacturers.

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19. Works with any cell chemistry - past, present and future

    The key word here is “future”. Battery technology is continually improving. Two key areas of focus are higher energy density and lower internal impedance.

    The process that True Balancing uses to charge and balance the current generation of lithium-ion batteries will be just as effective at charging and balancing future generations of batteries.

    All of the benefits of True Balancing presented in this document will add great value to battery packs until someone develops the “perfect battery” – a battery in which all cell characteristics are perfectly identical for the entire life of the battery.

    And it will be a long time until that happens.

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20. Reduced cost of service calls → happier customers → fewer warranty claims

    This is an indirect benefit of True Balancing that is particularly applicable to EVs.

    EVs that have True Balancing in their battery packs will perform better. They will have longer driving range and will experience less decline in range over many charge cycles and many miles driven. True Balancing will provide early detection of failing cells, warning the user to bring the vehicle in for service before the battery fails on the road.

    This leads to a better driver experience with the vehicle and greater customer satisfaction. And that results in *fewer customer complaints, fewer service calls and fewer warranty claims related to battery performance.*

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21. Give a 2nd life to used batteries

When batteries reach end of life, they usually aren't dead yet.

EV batteries are typically considered to be at end of life when SOH drops to somewhere around 70% or 80%. That means that the battery has lost between 20% and 30% of its nominal capacity.

With passive balancing systems, most batteries will get out of balance at some point. And out of balance cells cause a decline in SOH. A battery at 70% SOH may appear to be dead, but it may have a lot of remaining service life. The problem is that the BMS cannot get the cells back into balance, causing premature end-of-life.

True Balancing can give a 2nd life to these batteries. If the BMS is upgraded to True Balancing and the battery goes through one full charge cycle, the cells are brought back into balance. This will bring SOH up to a higher level and the battery can be put back to use in a new application, for example in energy storage systems.

True Balancing will keep the battery operating at peak performance and will maximize the 2nd life of the battery.

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22. Environmentally Friendly

As explained previously, True Balancing maximizes battery capacity and maximizes battery life. So if you have True Balancing in your battery, all of the materials and components that make up the battery are utilized to the greatest extent possible. This reduces the natural resources that are consumed to make batteries.

True Balancing further reduces natural resource consumption by providing a viable second life to many batteries that have reached end of first life.

This makes True Balancing the most environmentally friendly battery management technology available today.

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23. Less stress on the cells

Repeated charge/discharge cycles cause cells to degrade. The electrochemical capacity of the cell declines and mechanical structures within the cell weaken and start to break down. This is what causes batteries to die.

Passive balancing systems accelerate cell degradation. Passive balancing systems steadily drain energy out of the highest SOC cells. This is effectively a “mini-discharge” cycle. The effect of one such mini-discharge cycle is small, but the effect is cumulative over many charge/discharge cycles and it shortens the life of the battery.

What’s particularly insidious about this problem is that the smallest, weakest cells reach FCV first. (The stronger, higher capacity cells need more time to reach FCV.) So with passive balancing systems, the weakest cells are subjected to the most stress, which is the opposite of what you want.

True Balancing breaks free of this pattern of “mini-discharge cycles”. During charge cycles, True Balancing brings each cell up to 100% SOC on a steady, positive path. There is no need to drain energy from cells when they approach full charge. This reduces cell degradation and helps to maximize battery life.

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24. Supply Chain Resilience

This is the last of the benefits of True Balancing. Congratulations! You made it to the end of the list!

Supply chain interruptions can be very costly. This became apparent during the Covid pandemic.

True Balancing is highly immune to supply chain interruptions. The entire True Balancing circuit can be made with common components (transistors, inductors, diodes, resistors and capacitors) that can be purchased from many different suppliers.

You can assemble a complete True Balancing system without using any single-sourced components. If you have had problems with single-sourced components that go on allocation, you should consider using True Balancing in your batteries.

Thank you for going through this entire list. If you would like to learn more about how you can add True Balancing to your batteries, please contact us at clint@truebalancing.com

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