NeverDie® Battery Management System
Section 1: Overview

PURPOSE:

- ✓ A Battery Management System or BMS Protects the Battery From Being Damaged by External Sources
- ✓ A BMS Protects the User and the External Sources from a Failed Battery
- ✓ A BMS-Based Battery is "Intelligent" and Makes Decisions Using Microprocessors, Sensors and Pre-Programmed Software-Based Values or "Trigger Points"
- ✓ It Becomes Essential that the User of a BMS-Based Lithium Ion Battery Understands both the 'Behavior Pattern' of an Intelligent Battery and how that Battery will Interact in the Installation
- ✓ THE GOALS:
- ❖ **Battery Safety**
- ❖ **Installation Safety**
- ❖ **Long Battery Life and Return-on-Investment**
- ❖ **Prevent Unexpected Behavior Patterns**
- ❖ **Obtain Real, Measurable Performance Gains in your Application**

NeverDie® Battery Management System
Section 1: Overview

Key Terms and Definitions:

- BMS: Battery Management System, Necessary for Battery Safety and Cell Life
- BMS Ensures that all Internal Cells are Acting in Union During Charge and Discharge Cycling
- BMS Monitors and Takes Action to Shut-Down the Battery if Just One Cell is Failing or if the BMS itself is failing (a NeverDie® exclusive)
- LVC: Low-Voltage Cutoff, or, the Point Where the NeverDie® BMS Will Force the Battery into Sleep-Mode, with or without a Power-Reserve
- RVC: Reserve Power Cutoff, the BMS shuts off at 'low fuel' or 10% Reserve
- LVC is Required to Prevent Cell Failure by Over-discharging and reverse-polarity
- DVC: Dead-Voltage-Cutoff: a battery that enters sleep-mode at DVC must be fully recharged to reactivate the BMS
- HVC: High-Voltage Cutoff, or, the Point Where the BMS Will Stop the Charging Current to Prevent Thermal-Runaway OR Enter Sleep Mode (<u>User Decision</u>)
- HVC Also Occurs When Cell-Balancing is Underway but becomes Excessive
- Shunting: A Necessary Function to EQUALIZE or re-balance Individual Cells with Natural Small Differences in Capacity and Resistance/Impedance. Used to Ensure All Cells are Brought to near-100% State-of-Capacity. Shunting Occurs Near the End of the Charging Stage (Called Top-End Shunting)

NeverDie® Battery Management System
Section 1: Overview

Key Terms and Definitions:

- 4M or 8M: A MOSFET-type NeverDie® BMS normally use for engine starting batteries that removes the HVC disconnect feature, thus allowing the battery to become a 'voltage dump' for a failed alternator or charging device. It is preferred to sacrifice the battery versus permitting a possible alternator/generator/wire-harness fire. Sometimes called an Open-Loop system.
- FEC: Field Effect Control. A NeverDie® BMS feature that senses a failing alternator or incoming over-charge voltage/current and takes action to de-energize the alternator/generator field to prevent tripping HVC. It saves the alternator, saves the battery, and allows full discharge of the battery down to LVC versus a sudden battery disconnect at HVC. Also called a Closed-Loop system.
- AGR: Automatic Generator Restart. A NeverDie® BMS feature that sends a signal at low-battery levels to start a charging device or generator and in turn will stop that device when the battery level reaches 100%. A Closed-Loop system.
- Dual-Channel NeverDie®: A BMS that separates the incoming charge current from the discharging current via two independent conductor paths. This permits HVC to occur (to disconnect a charging source) without interrupting power flow. An important feature when a customer has multiple charging sources (wind, solar, generator) and it is critical that in the event of a failing charging source the power remains available from the battery. A Closed-Loop system.

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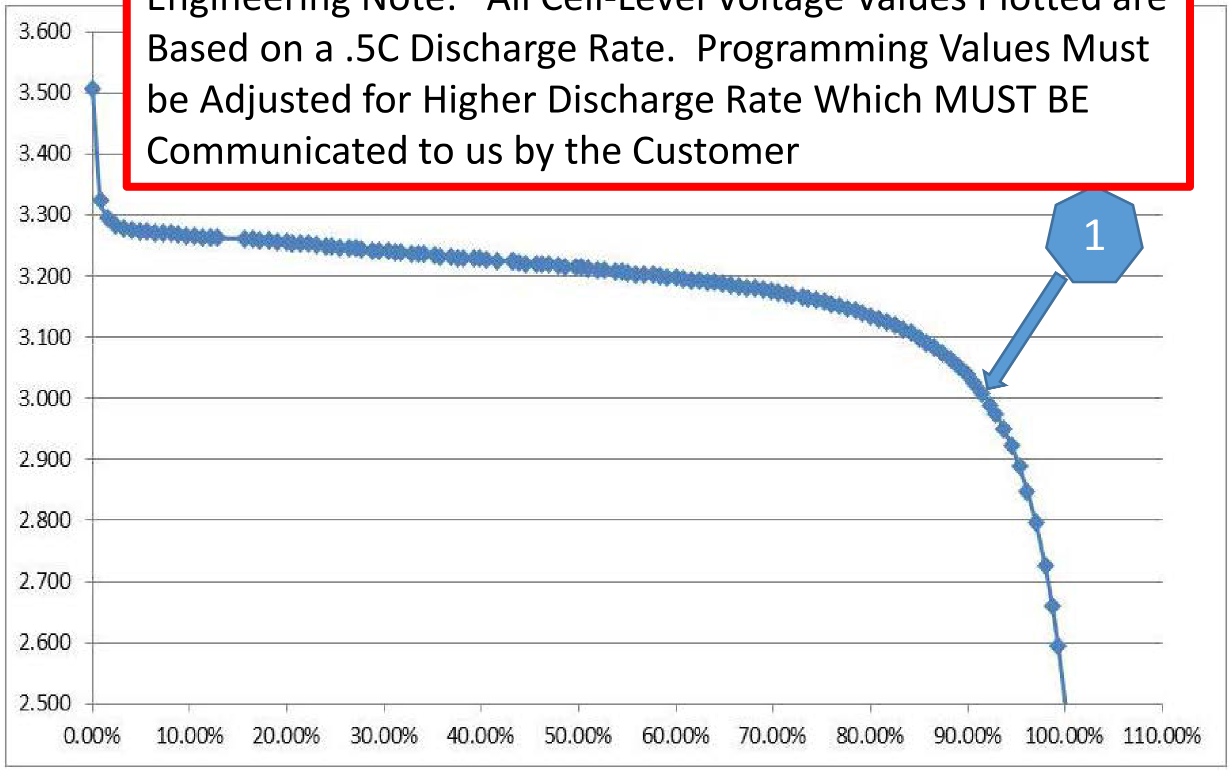
NeverDie® Battery Management System
Section 2: Overview, DISCHARGE CURVE "Per Cell"
The BMS Monitors Each Cell at 3.2V Nominal AND at Gross-Pack-Voltage (I.E. the Total Charging and Discharging Voltage)
NOTE: "State-of-Charge" or SoC Cannot Be Accurately Measured Based on Voltage Readings Other Than at HIGH and LOW Fuel Levels

Engineering Note: All Cell-Level Voltage Values Plotted are Based on a .5C Discharge Rate. Programming Values Must be Adjusted for Higher Discharge Rate Which MUST BE Communicated to us by the Customer



LiFePO4 Power-Type Cell Discharge Curve (Per Cell)

- At a discharge rate of ½-Capacity or .5C (50 amps continuous on a 100 amp-hour cell shown) the graph represents voltage readings take at various depths-of-discharge
- 12 Volt: Multiply the Voltages X 4 (Cells)
- 24 Volt: Multiply the Voltages X 8 Cells
- 36 Volt: Multiply the Voltages X 12 Cells
- 48 Volt: Multiply the Voltages X 16 Cells

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Example: Point 1 is 3.0 Volts at Approx. 90% Depth of Discharge Under a .5C (1/2 Battery Capacity) Load: 4 Cells X 3.0 = 12.00 Volt Output at 10% of Remaining Capacity

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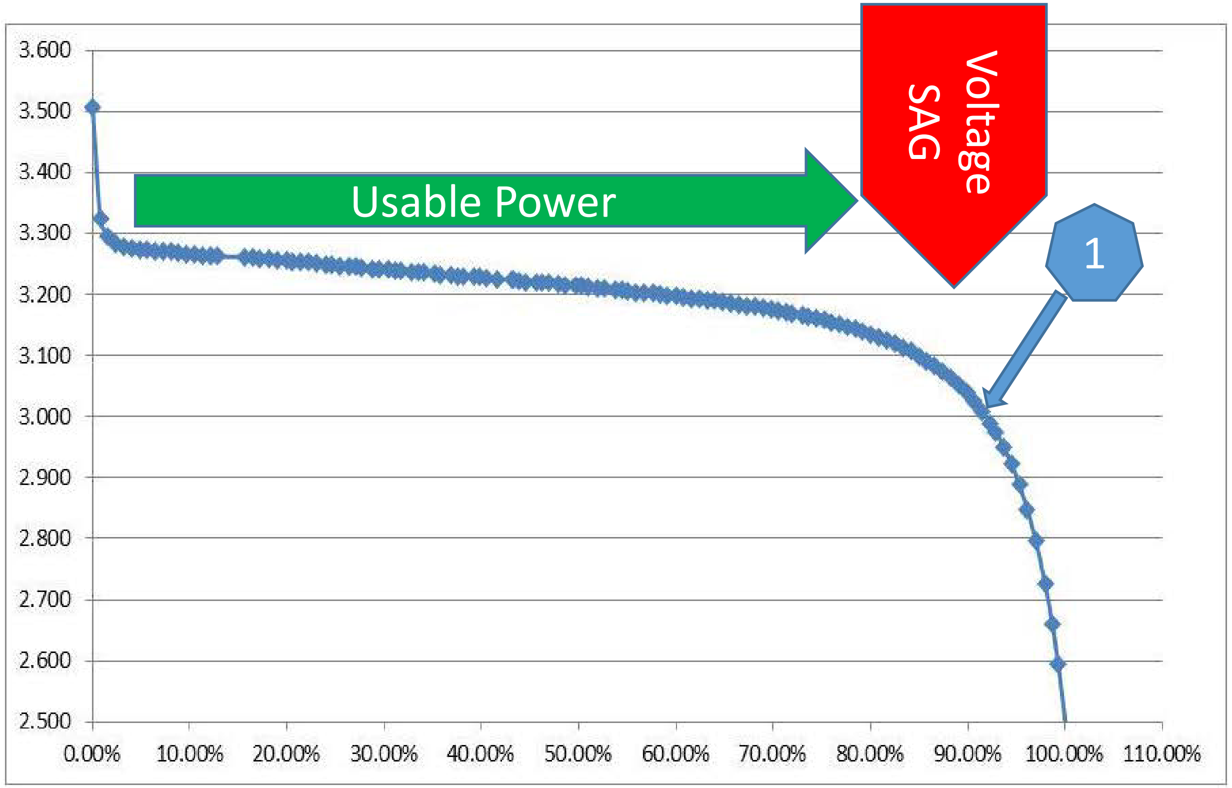
FLAT VOLTAGE DELIVERY CURVE UNDER a .5C LOAD:

DELIVERY OF HIGHER QUALITY VOLTAGE DOWN TO 90% DEPTH OF DISCHARGE: Note 1 Demonstrates that Under Load, Our Power-Cell Lithium Batteries Deliver 12.0, 24.0, 36.0, 48.0, etc Volts or **Higher** Down to 10% Remaining Fuel. This Number is Substantially Improved Over Other Chemistries. ***<u>What This Means……….</u>***



1. **An existing voltage-based meter system installed and based on older battery technology will no longer function and will require a replacement device from Lithionics Battery.**
2. **It normally safe to claim that the devices powered by this quality of voltage will consume less amp-hours, will improve in performance, will run cooler and last measurable longer.**

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Example: Point 1 is 3.0 Volts at Approx. 90% Depth of Discharge <u>Under Load:</u> 4 Cells X 3.0 = 12.00 Volt Output at 10% of Remaining Capacity

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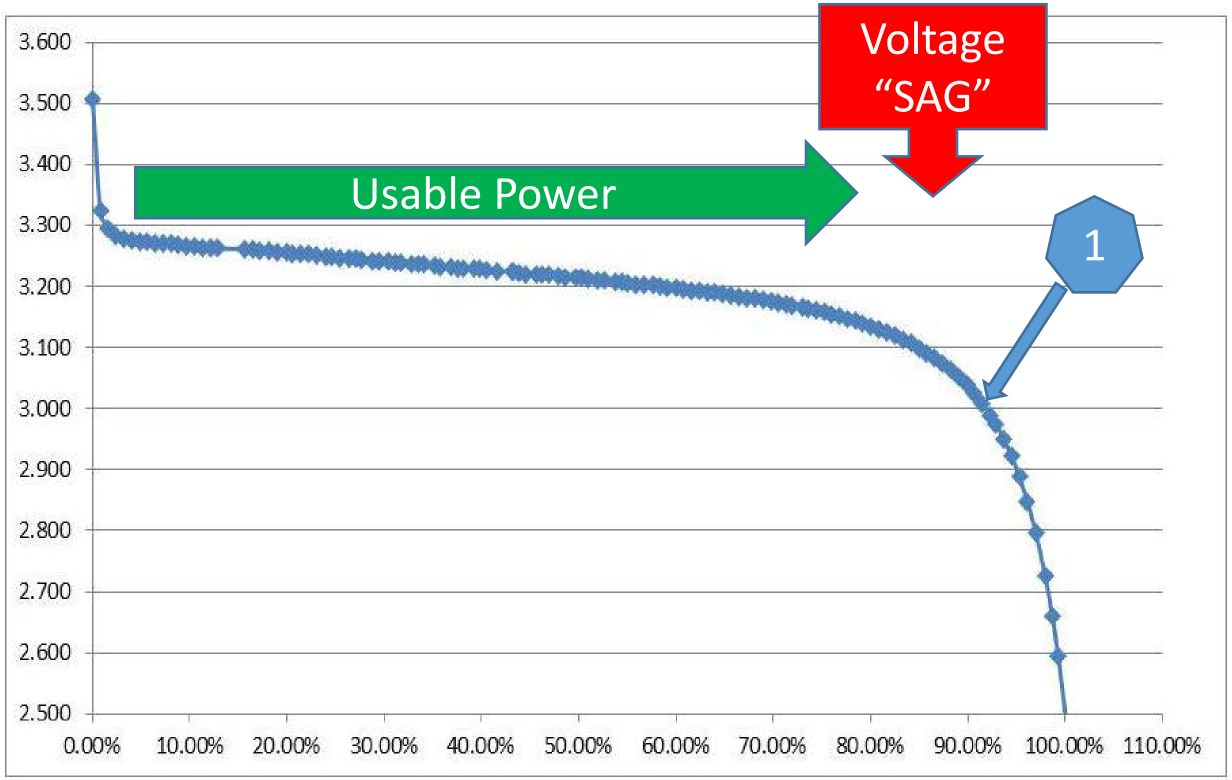
Sizing the Battery, Setting the BMS "Trigger Points" (Software Values)

Voltage 'Sag' begins at a point that is a function of the size (ampacity) of the battery and the load being placed. Low voltage therefore occurs at either low state of charge (near-empty which is normal), or under heavy load (which may be abnormal.) BMS triggers points can occur from either condition.



1. **Example: a vehicle encountering a steep hill**
2. **Example: a long cranking cycle on a diesel or turbine engine**

These events can incur a BMS trigger point and must be adjusted by changes to the software if necessary. The trigger points are either determined by customer-funded development or after-installation, requiring a BMS software adjustment. In extreme cases, more battery capacity may be required and purchased by the customer

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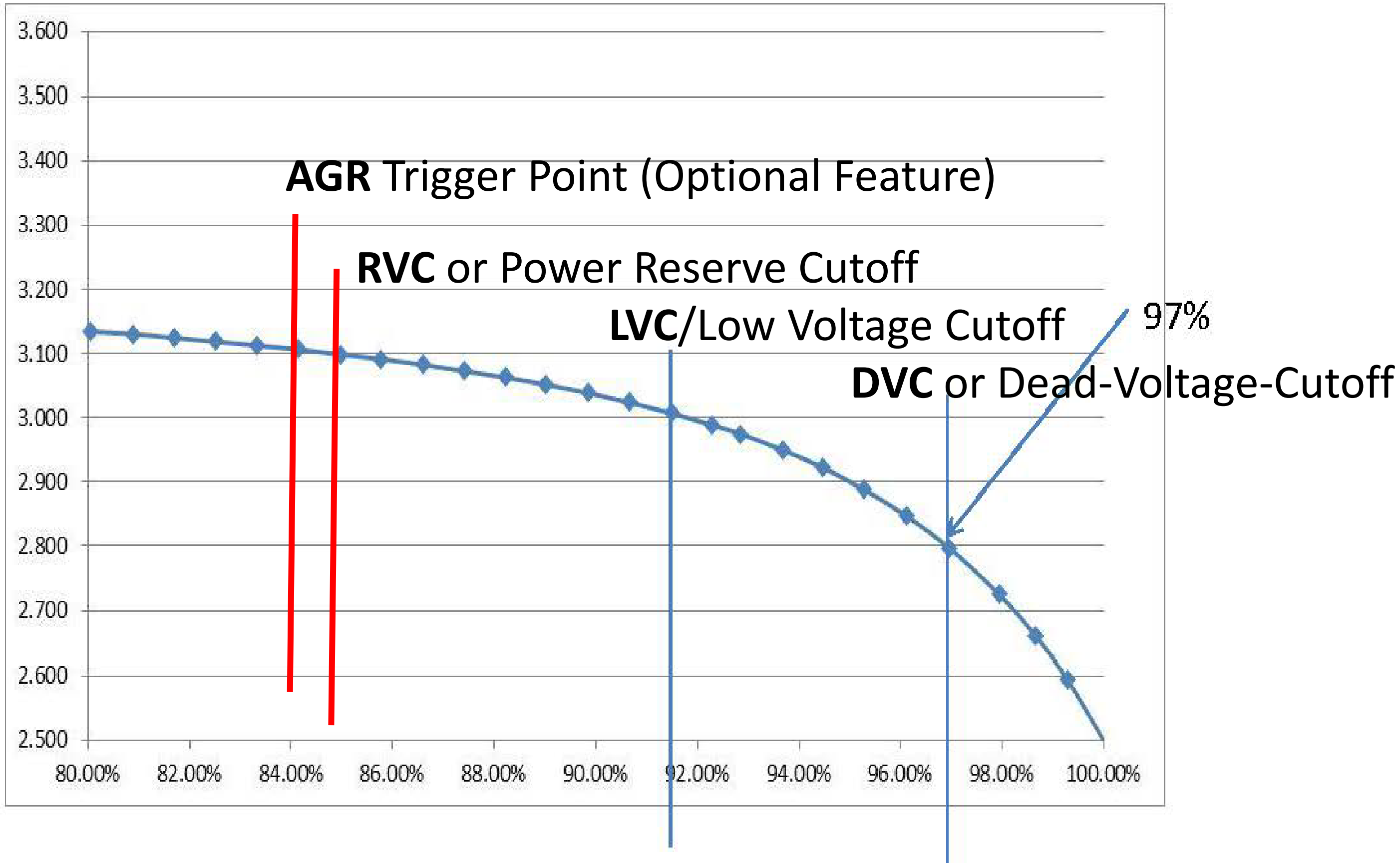
NeverDie® Battery Management System

Section 2: Standard Programmed Trigger Points for AGR/RVC/LVC/DVC

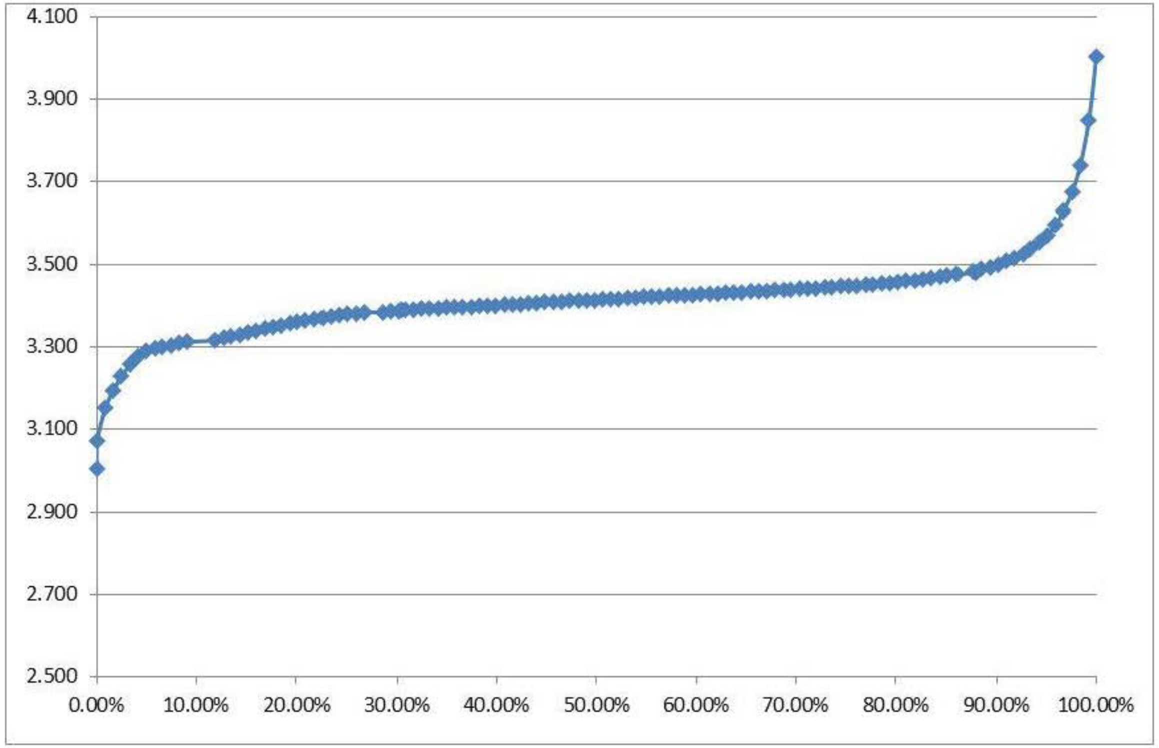
All Trigger Points Are Programmable in the NeverDie® BMS by Changes in Software Not Hardware (Quickly Changed at No Cost)



Notations: STANDARD FACTORY SOFTWARE SETTINGS

- ✓ AGR: At 3.1 Volts per cell, the optional AGR signal is triggered to start-run a diesel or gas generator. A 10 second delay occurs at 3.0 volts per cell and the generator must commence charging within 20 seconds.
- ✓ RVC: At 3.0 volts per cell or 90% Depth-of-Discharge, the battery will shut-off. Press the stainless steel reset button to access an additional 10 to 12 percent power-reserve. For a 12V system, the trigger point is 12.0V
- ✓ For a 24V system (25.6 nominal voltage), RVC occurs at 3.0V X 8 cells = 24.00 volts
- ✓ For a 48V system (51.2V nominal voltage), RVC occurs at 48.00 volts
- ✓ After RVC is activated, the battery will discharge to DVC or Dead-Voltage-Cutoff. At DVC, the battery must be fully charged to 100 percent SOC (State-of-Charge) in order for BMS to re-activate.
- ✓ At DVC, press reset button and the BMS will 'wake up' for 30 seconds only. A charger must be applied within 30 seconds and a voltage-rise recorded by the battery or battery will re-enter 'sleep mode' (if this condition continues and prevents charging, contact the factory to receive instructions on charging to the SERVICE TAP terminal)
- ✓ A battery that enters DVC must be IMMEDIATELY recharged to prevent battery damage
- ✓ LVC: an optional trigger point setting, permitting a lower depth of discharge (must be factory approved)

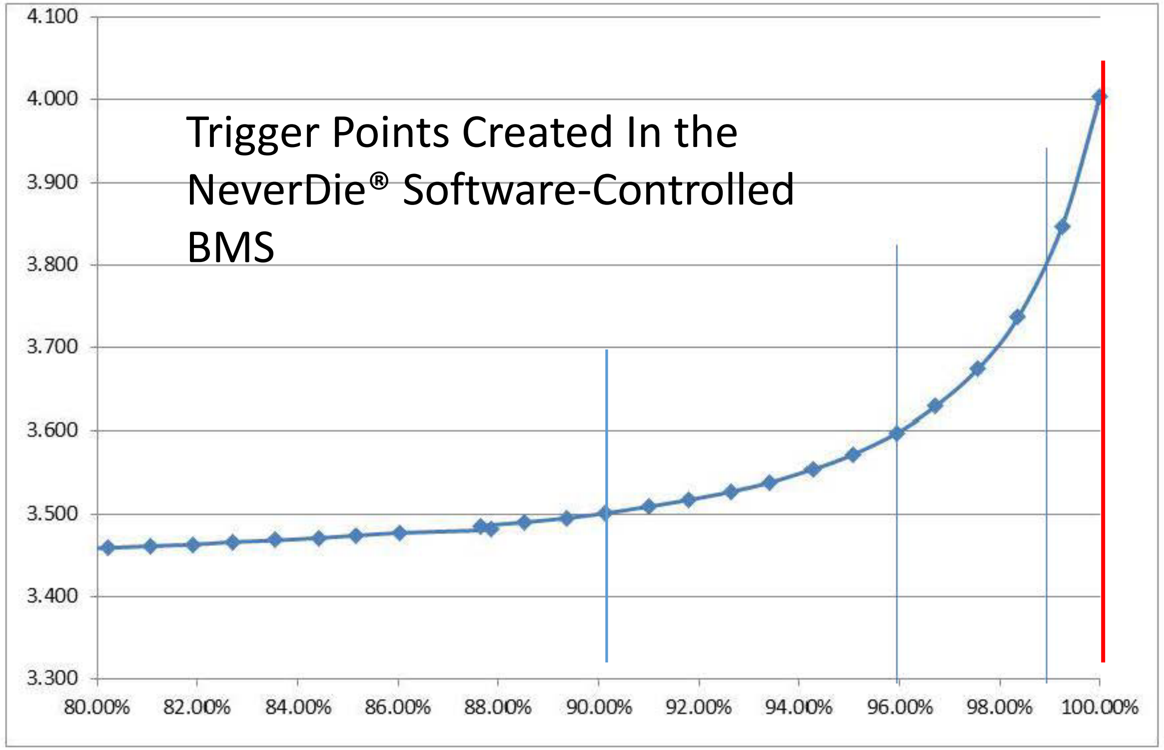
NeverDie® Battery Management System
Section 2: Managing HVC or High-Voltage-Cutoff and Top-End Shunt-Type Cell Balancing Operations
OVERVIEW: The curve is reading the battery voltage response to a charge input (not the voltage of the charging device)



LiFePO4 Power-Type Cell CHARGE Curve (Per Cell)

- This Section Describes How the NeverDie® Controls Safe Recharging
- Notice How the Lithium Cell Exhibits a Rapid Voltage Rise Near the End of Its Charging Cycle
- **It is for This Characteristic That Many Lithium Cell Failures Are Caused By Charging Close to the Point of the "Exponential" Voltage Rise or By Using Incorrect Chargers**

NeverDie® Battery Management System
Section 2: Managing HVC or High-Voltage-Cutoff
EXPLANATION



LiFePO4 Power-Type Cell CHARGE Curve (Per Cell)

- The Graph is Now Enlarged to Show the END of the Charging Cycle
- All Lithium Cells Must Be Re-Balanced or Equalized During Recharging to Account for Differences in Capacity. This is Called Shunting. When the First Cells Reaches 100 Percent ‘Fill’ It Begins to Shunt or Bleed-Off Excess Charging Current Waiting for the Weaker Cells to ‘Catch Up’ to 100% State-of-Charge
- Continued on next page…..

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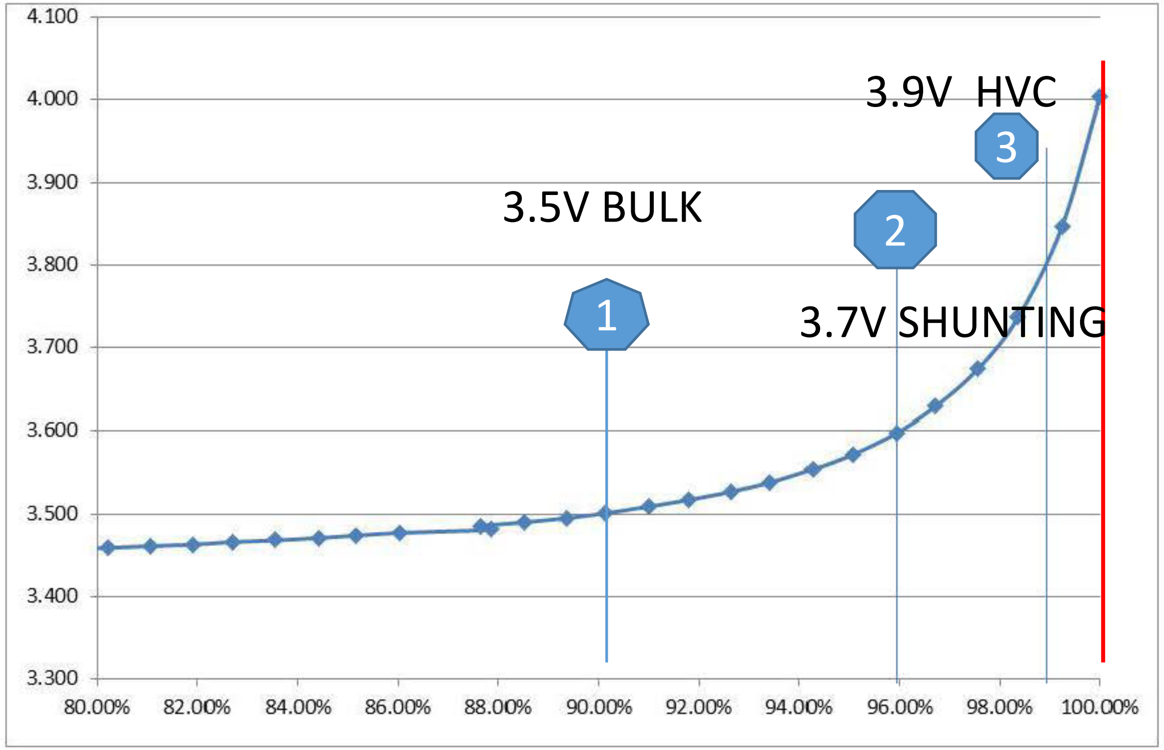
NeverDie® Battery Management System
Section 2: Managing HVC or High-Voltage-Cutoff
Lithionics Battery Products are Able to be Charged via GEL-Settings on Approved Lead-Acid Chargers **OR** Lithium Ion Chargers using CCCV Algorithms



LiFePO4 Power-Type Cell CHARGE Curve (Per Cell)

Point 1: BULK STAGE GEL ALGORITHM SETTINGS

- The recommended BULK charging voltage of NeverDie® Batteries,, the GEL Battery Charging Algorithm: 14.0, 28.0, 42.0 and 56.0 Volts for Common Voltage Systems.

Point 2: ABSORB Stage and SHUNT Stage

- The Voltage at Which We Begin to SHUNT Each Cell to Achieve Cell Balancing (Re-Balancing)
- Our charger has dropped the voltage to 3.4 volts per cell or 13.6, 27.2, 40.8 or 54.4 volts for systems
- From Point 1 to Point 2 We Perform 'Soft-Shunting' or Variable-Rate Shunting to Prevent Stress to the Balancing Electronics

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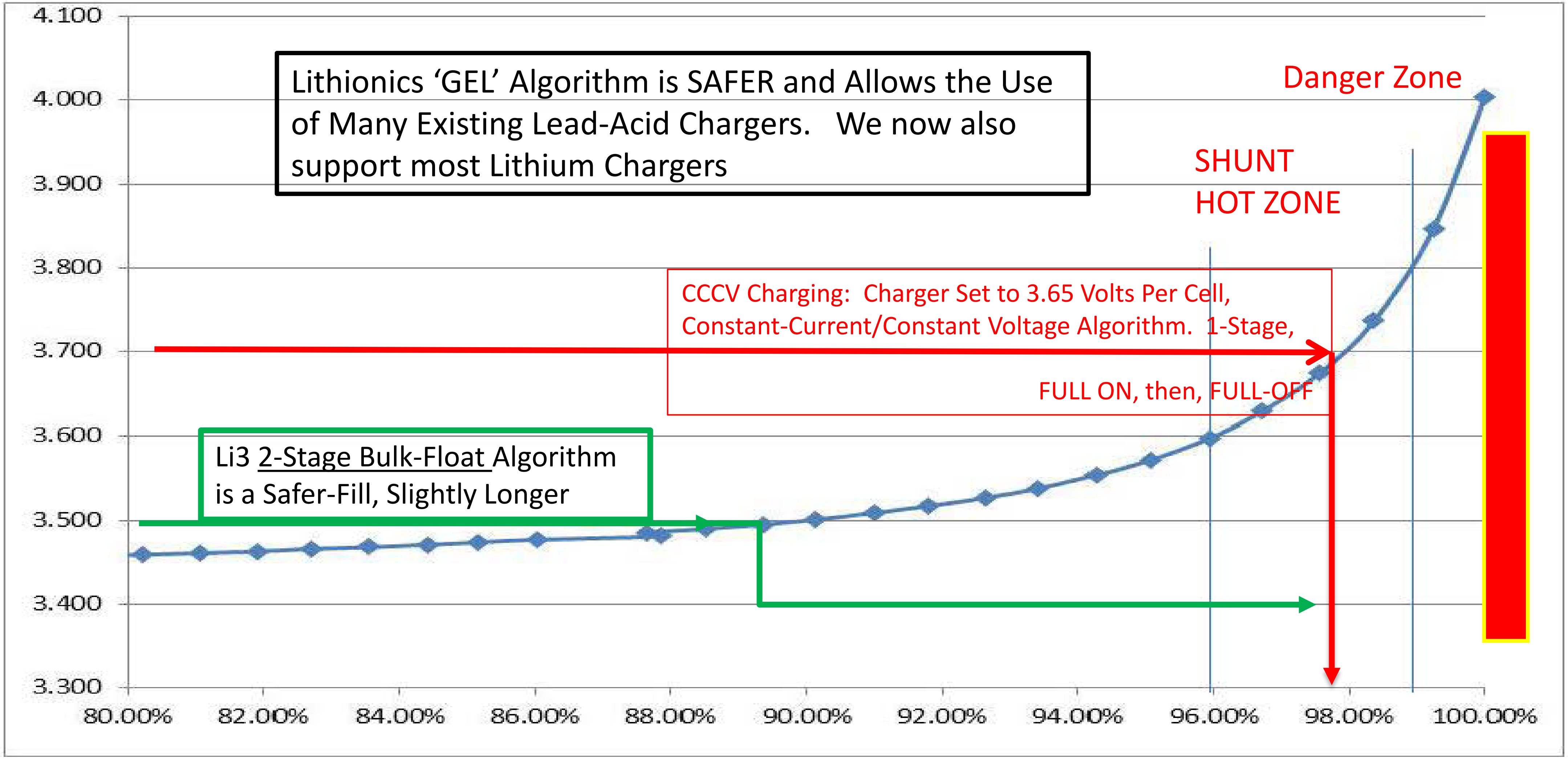
PREVENTING SHUNT BALANCER FAILURES

- **Lithium Ion Cells and BMS Electronics fail on VOLTAGE not CURRENT**
- **We have developed a lower-voltage algorithm to achieve full-charge and avoid cell and balance-shunt failures**



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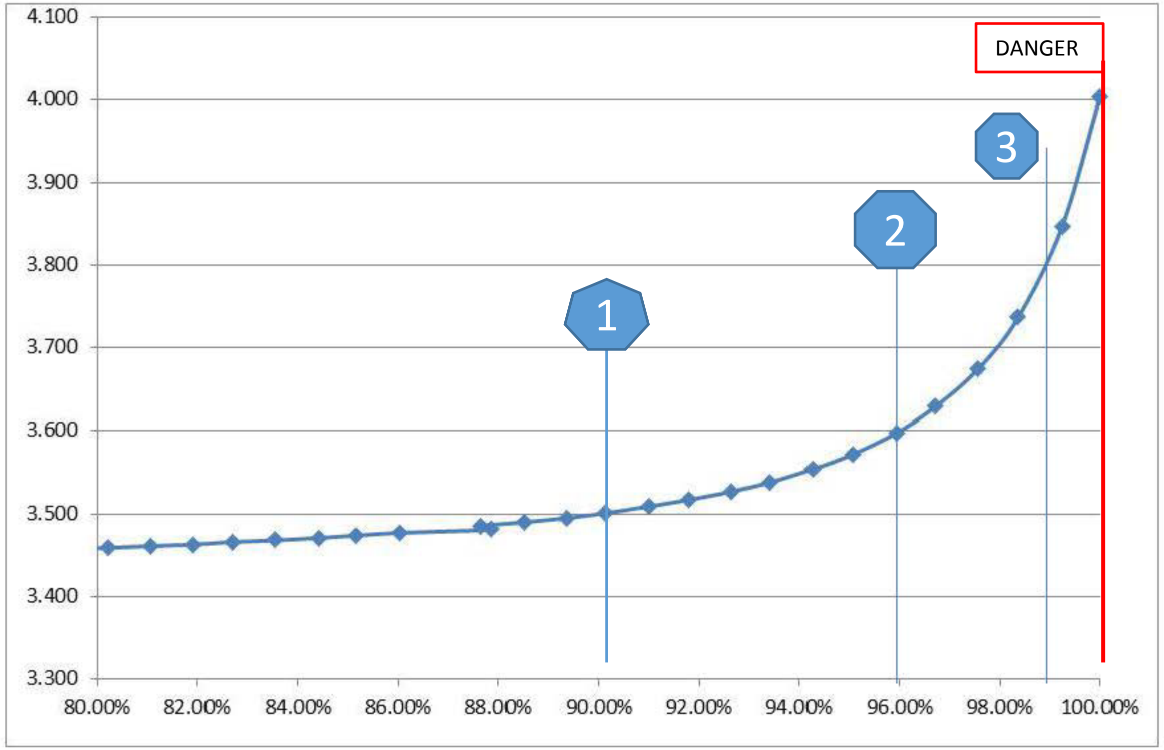
NeverDie® Battery Management System
Section 2: Managing HVC or High-Voltage-Cutoff
EXPLANATION



LiFePO4 Power-Type Cell CHARGE Curve (Per Cell)
Point 2 to Point 3:

- At 3.7 Volts Per Cell, the NeverDie® Balancing System is Shunting at a Full Rate. This Allows for Some Voltage Inaccuracy When Non-Lithium Chargers are in Use by the Customer (Magnum, Outback, Xantrex for example)
- Full Shunting Continues from 3.7 to 3.9 Volts per Cell. In this Range the BMS Permits Full Charging without 'Tripping' the HVC Disconnect. For a '12V' Battery, the Voltages would be 14.8 to 15.2 Volts. Not Recommended, but, Tolerated by the BMS
- For Safety Reasons, The BMS will Trigger HVC (Disconnect) at **Point 3** if Either 1 Cell Reaches >3.89 Volts or The Temperature Sensors Detect High Heat from Shunting

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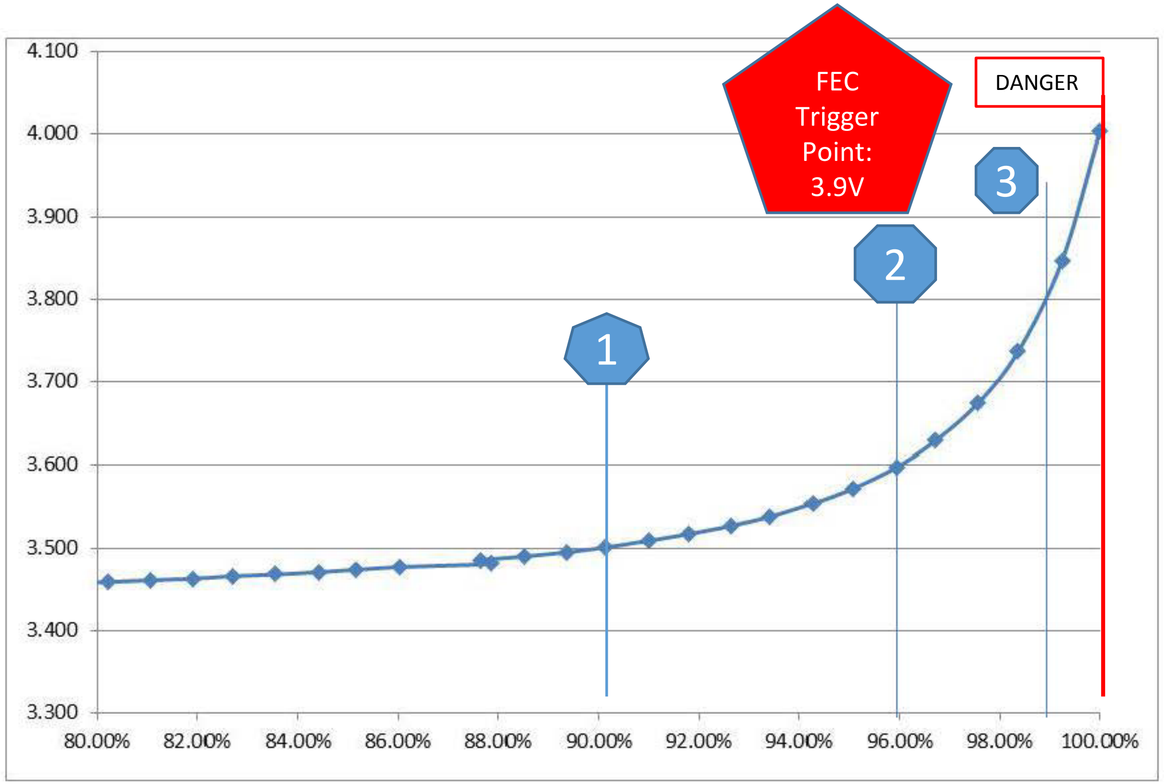
NeverDie® Battery Management System
Section 2: Managing HVC or High-Voltage-Cutoff
Alternator Safety: Managing Battery Cut-Off and Alternator Protection
Is called FIELD EFFECT CONTROL

LiFePO4 Power-Type Cell CHARGE Curve (Per Cell)



SUMMARY

- If the NeverDie® BMS Trips the HVC Disconnect Point, it Simply is Entering Sleep Mode and Taking the Battery Off-Line to Prevent Further Charging.
- **OPTION: Features Are Available to Allow the BMS to 'Throttle' or Control the Charging Source to Prevent BMS Disconnect During Charging. Examples: FEC, Dual-Channel BMS, Charger Interlock Relay**
- When SHUNTING is Complete, the NeverDie® Will Automatically Turn the Battery Back to ON (AUTO RE-ENABLE)
- If being charged via Alternator, a failing alternator must be de-powered by the BMS to prevent alternator over-heating or a fire as a tripped BMS no longer allows the battery to be a voltage-dump.
- FEC: if overcharging is sensed by the BMS, the FEC will trigger a shut down of either the IGNITION INPUT or the FIELD WIRE of the alternator, protecting both battery and alternator