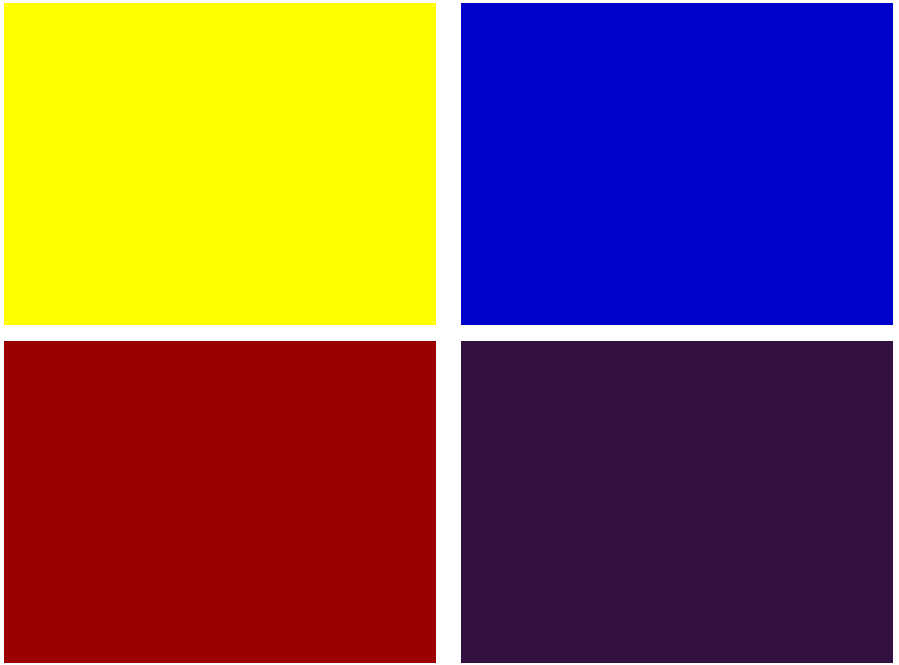
Controlled Overcharge of ESS Lead Batteries

CBI Virtual Workshop
May 19, 2020



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- **Testing & Certification**
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- **Battery Applications**
  - Simulation Testing
  - Control Strategies
- **Research & Development**
  - Mechanistic Studies
  - Failure Analysis
- **Consulting Services**
  - Energy Systems
  - Project Management
- **Systems Development**
  - Monitoring
  - Analysis

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Project Objective

- Determine if a minimum-overcharge/high level PSoC methodology, or the controlled overcharge protocol, applied to gel and standard AGM products can provide similar life-extending benefits as shown in previous pure-lead AGM testing.
- Determine if the controlled overcharge protocol can be effectively applied to multiple parallel strings of numerous series connected cells required to provide the varying capacity needed for different Energy Storage Systems (ESS) installations.
- Can the controlled overcharge protocol enable lead-acid batteries to meet the life cycle and capacity turn-over (CTO) requirements of the emerging ESS market and support CBIs key performance indicators.

CBI Roadmap KPIs Targeted

- Increasing cycle life to target the 2025 PSoC, PV of 2,500 cycles
- Reducing overcharge increases efficiency therefore target is the 2025 charge efficiency of >95%

1.13 Key Performance Indicators for ESS batteries

Indicator	2019	2022	2025
Service life, Y	12+	12-15	15-20
PSoC, PV	1500	2000	2500
Cycle life	1000 - 3000	5000	6000
Charge efficiency	85 – 90%	90 – 95%	> 95%

Table 5 - Key Performance Indicators for ESS batteries.

The main areas for improvements to lead ESS batteries are in cycle life and PSoC cycling particularly when used with solar PV charging as highlighted in yellow. Service life can be achieved if the cyclic requirement is limited but to effectively use cycle lives of 5000 cycles or more the calendar life must be in the range of 15-20 years. Charge efficiency requires careful charge management as well as improvements in battery design.

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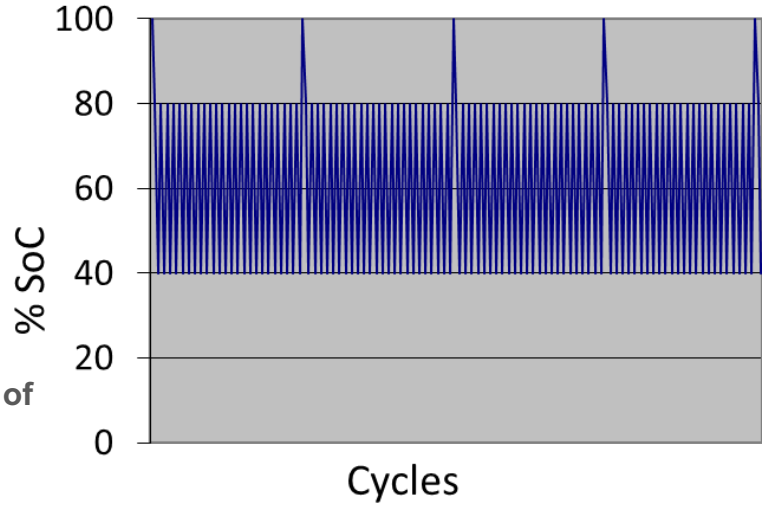
Background

- Controlled overcharging on thin-plate, pure lead AGM 12V monoblocs operating under 30% PSoC conditions with a high level SoC have been shown to deliver in excess of 5,500 cycles, equivalent to 1,650 CTOs. The overall profile being indicative of applications such as load-levelling or peak-shaving. (Frank Fleming; Clever Electronics for Large Battery Arrays, European Lead Battery Conference Presentation, Vienna Austria, September 7, 2018)

- Still unknown is how other lead-acid battery technologies, gel and standard (non-carbon enhanced) AGM products, would benefit from controlled overcharge in PSoC operations. Similar life-extending benefits in these products would make them more suitable for ESS applications.

Traditional Partial State-of-Charge (PSoC) Operation

- Compared to standard cycling algorithms
  - Significant reduction in overcharge
  - Reduction in gassing and corrosion
  - Improved efficiency
  - Greater capacity turnovers (CTOs)
  - Reduction in overall charge time
- However
  - Battery operates continuously below a full state of charge - reduced available battery capacity
  - A periodic equalization charge required to maintain capacity



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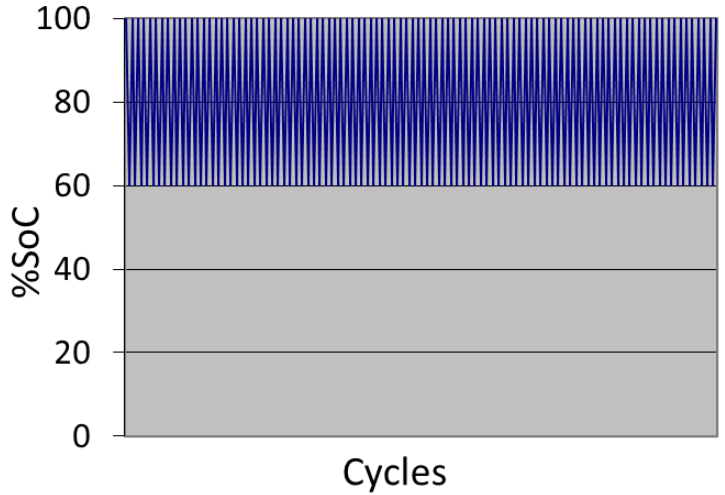
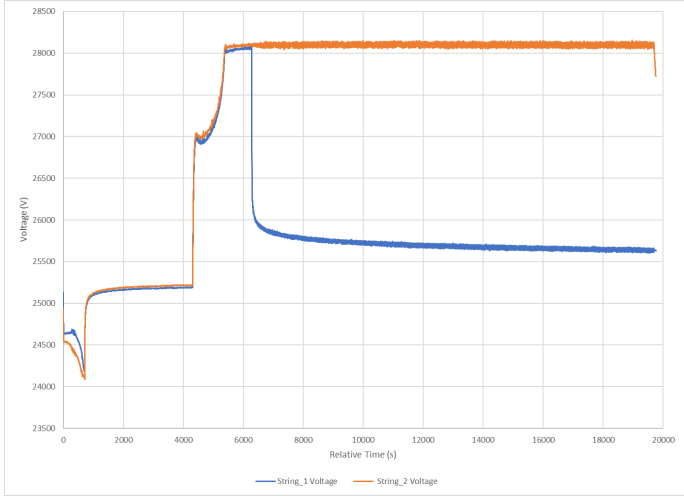
Minimum Overcharge High Level PSoC Duty – Controlled Overcharge Protocol

- Achieved by delivering well controlled, very low levels of overcharge throughout life
  - Significantly less than typical algorithms (≈ 101-103%)
  - Overcomes charge inefficiency
  - Targets 100% SoC
- Top SOC during operation is maintained very close to 100%



Test Protocol

- Each battery pack will be subjected to a charge-discharge cycle consisting of:
  - C/5 constant current discharge to 40% DOD of the pack capacity
  - C/5 constant current to a constant voltage charge to a fixed overcharge percentage based on actual capacity discharged per string
- Rests to ensure max operating temperature < 45°C
- No interim performance tests will be performed to not positively or negatively affect the outcome. Module and string end-of-discharge voltages will be monitored throughout to determine degradation with end of life being when either a module or sting reaches 1.75 V/cell.
- Testing duration is estimated to be 18-months to achieve approximately 2,000 cycles (800 CTOs)



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Battery Selection

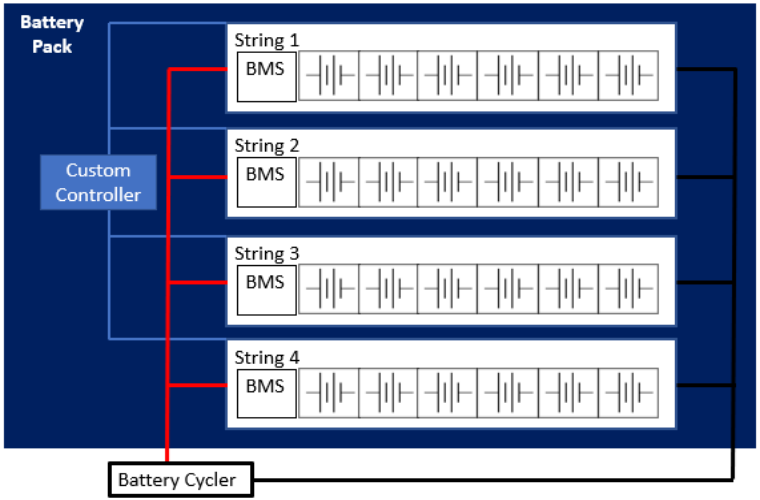
- Premise that conventional, non-carbon enhanced lead-acid battery constructions can achieve similar cycle-life improvements as previous testing on thin-plate pure lead battery constructions
- Two different commercially available battery types were selected
- A gel type with specifications:
  - 12V nominal
  - 120 and 105 Ah at C/20 and C/5 rate
  - Due to COVID-19, battery delivery delayed to June
- Standard, non-carbon enhanced, AGM construction with specifications:
  - 8V nominal
  - 160 and 130 Ah at C/20 and C/5 rate
  - 16 modules delivered with remaining delayed due to COVID-19

Initial Overcharge Characterization

- Samples of each battery construction are to be cycled at the module level under the protocol previously described utilizing different overcharge percentages based on the actual capacity discharged.
- A range of 101% to 103% percent overcharge produced the best results in previous testing, therefore the chosen range for this characterization.
- Gel batteries overcharge levels will be 101%, 101.67%, and 102.4%
  - Testing will begin upon battery arrival
- AGM batteries overcharge levels are being tested to 101.5%, 102.3%, and 103.1%
  - Test has just started
- The Gel batteries overcharge characterization range being lower because of the general lower internal resistance.

Battery Packs

- Packs will consist of four parallel strings at a nominal voltage of 72V.
- AGM battery pack will consist of six series connected modules per string due to the 12V nominal module voltage, 24 modules total.
- Gel battery pack will consist of nine series connected modules per string due to the 8V nominal module voltage, 36 modules total.
- Using electronic controls, each string will be monitored and controlled such that the overcharge is specific to the capacity discharged from each parallel string.



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Electronic String Control

- Each string will have the following characteristics monitored using a battery management system communicating to a single board computer (SBC) running BMS software.
  - String Voltage
  - String Current
  - Min module voltage
  - Max module voltage
  - Cumulative charge capacity
  - Cumulative discharge capacity

- The system will actuate a contact which will control when each string charge is terminated based on measured capacity and the pre-determined overcharge percentage.
- Data is logged by the SBC software with measurements being provided by the BMS

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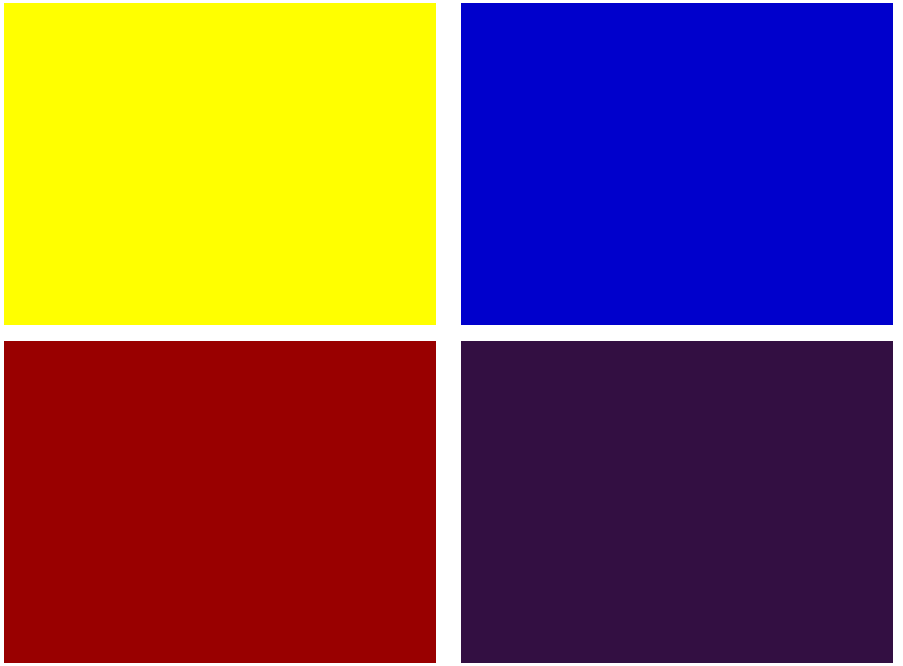
Thank You



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