ZincFive

WHITE PAPER

New Battery Capability for Dual-Use UPS and AI Factory Dynamic Power Management

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ABSTRACT

Artificial Intelligence (AI) data centers with Graphics Processing Unit (GPU)-centric designs create increasing IT rack power density and power supply stability challenges. The cyclical nature of GPU-centric AI processing creates dynamic power demand that is 50% or greater than the average continuous IT rack load power, with load transients that typically last up to a total of 50 milliseconds (ms) per second, and transient load occurrence rates ranging from very infrequently to multiple times per second. This paper assesses the dual-use capability of nickel-zinc (NiZn) battery chemistry to mitigate AI dynamic loads while complementing well-established NiZn Uninterruptible Power Supply (UPS) backup power functionality. The conclusion is NiZn does exhibit required dual- use capability with demonstrated dynamic power cycle life performance exceeding 10 Million (M) cycles.

Keywords— AI data center, GPU, nickel-zinc battery, power transients, power density, AI pulse load mitigation, safety

I. INTRODUCTION

The emergence of Graphics Processing Unit (GPU)-centric Artificial Intelligence (AI) data centers poses significant energy and power management challenges for data center operators. Exponential increases in GPU rack power density, coupled with an increasing need for larger clusters of GPUs to support advanced AI training models, are the main drivers of increasing dynamic power requirements in AI data centers [1]. Adding to this burden is the nature of accelerated computing via GPUs, which results in dynamic power transients of 50% or greater than average continuous load power, typically, for up to a total of 50 milliseconds (ms) per second. Depending on the computational task, GPU load power transients may not occur, may occur only intermittently, or may repeat multiple times per second [2]. Operating GPU clusters in this fashion requires data center designers and operators to rethink the management of power transient impact, which varies based on GPU workloads and existing data center power infrastructures. One key question facing data center designers is where, in the power distribution system, is best to intercept dynamic power transients to minimize the impact of transient GPU loads on data center primary power sources. The answer to this question is based in part on the economics and technical feasibility of extending existing Uninterruptible Power Supply (UPS), in-rack Battery Backup Unit (BBU), or future sidecar AI data center infrastructure to provide desired dual-use backup power and dynamic power mitigation functionality. The urgency to find a dual-use solution is driven by the inability of lithium batteries or supercapacitors to provide dual-use functionality.

II. MOTIVATION OF WORK

Storing available energy in batteries and releasing it to support intermittent loads is a common solution for buffering the dynamics of renewable energy sources like solar or wind power. This work assesses the capability of nickel-zinc (NiZn) battery chemistry to similarly address AI data center dynamic power challenges. AI data center storage solutions require sub-millisecond response times, acceptable power and energy density, safe operation under all conditions, and sufficient dynamic power cycle life to support practical use in high-performance AI data center environments. NiZn battery chemistry is a well-known option for high-rate discharge applications like UPS, with fully demonstrated power density and reliability [3]. The motivation of this study was to evaluate the following key performance characteristics for assessing the suitability of NiZn battery chemistry as an AI data center dynamic power mitigation alternative to lithium batteries [4] or supercapacitors.

- **Response Time:** What is the discharge response time (e.g., on/off) of NiZn battery chemistry compared to the target of < 1 millisecond target?
- **Discharge Power:** Can NiZn battery chemistry provide acceptable discharge power for a 50 ms per second load profile?
- **Cycle Life:** What is the cycle life performance of NiZn battery chemistry for a 50 ms per second load profile?

III. EXPERIMENTAL SETUP

The test circuits shown in Fig. 1 were used to characterize the pulse power performance of a 1.8 Amp-hour (Ah), 3 Watt- hour (Wh) cylindrical model Z5 1.7-2 H X SC NiZn SubC cell with 2.2 cm diameter by 4.2 cm length dimensions. The initial 4.5 Million (M) pulse power cycles were conducted using a constant resistive load and a >60 watts per cell discharge target for 50 ms. The secondary 4.5 M to >10 M pulse cycle life tests were conducted using a standard Arbin LBT cycler programmed to provide a minimum 60 watts per cell constant power load. Both the 50 ms constant resistance and constant power discharges were followed by 950 ms of float recharge before the subsequent 50 ms discharge. The two sets of sequential test results are described below.

Total measured Capacity Turnovers (CTOs) for all three DUTs was >2,777 for 10 M cycles of 60 Watts Per Cell (WPC), 50 ms discharges from the 3 Wh NiZn cell. Actual CTOs exceeded this calculated result because average power discharged into the resistive load was greater than 60 WPC. At 10 M cycles, the State of Charge (SOC) was approximately 73% and recoverable State of Health (SOH) was 87%. This equates to the ability to support >2400, 50 ms per second discharge pulses (40 minutes maximum pulse load mitigation) without the need for recharging. Current ramp rate (di/dt) measurements conducted at the University of Texas, Arlington exhibited 2 A/µs response times, which equates to the delivery of 60 WPC (20 Energy Rate) of AI pulse load mitigation power in 25 µs, far exceeding the 1 ms response time requirement.

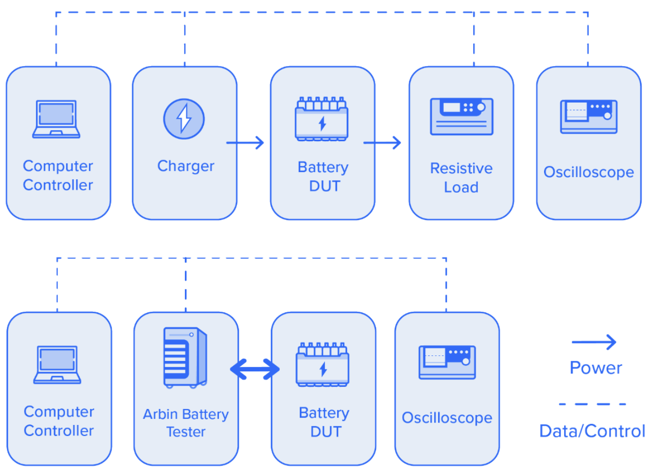

Figure 1: NiZn SubC cell Test Equipment

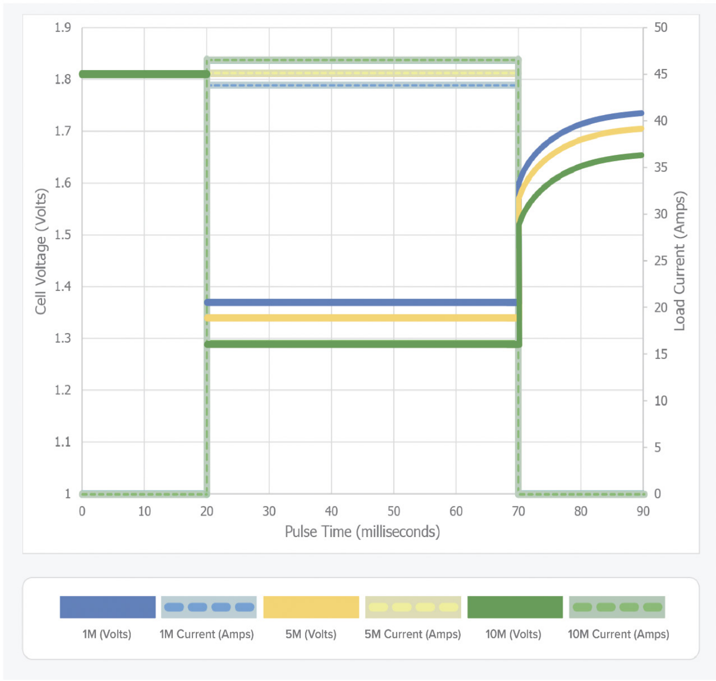

Figure 2: Cell 50 ms per second Cycle Life IV Curves

IV. INVESTIGATION AND RESULTS

Fig. 2 illustrates the average 50 ms per second discharge voltage and current characteristics of the DUTs 1, 2, and 3 at 1 M, 5 M, and 10 M pulse cycles, respectively. The average discharge voltage decreases with cycle count, with a concomitant increase in average current to maintain the imposed constant power pulse. Table 1 shows the temperature rise for the DUTs at all three cycle life check points. The DUTs were initially connected in a string, which is why the 1 M cycle results for temperature rise above ambient are the same for all three DUTs. The temperature of all DUTs increases with cycling which is consistent with expected aging effects and with the measured reduction in coulombic efficiency.

Table 1: Cell 50 ms per second Cycle Life Performance

Test Results	DUT 1	DUT 2	DUT 3
1 M Cycle Temp Rise	4.5 °C	4.5 °C	4.5 °C
5 M Cycle Temp Rise	7.3 °C	6.6 °C	5.8 °C
10 M Cycle Temp Rise	8.8 °C	9.0 °C	7.0 °C
1 M Cycle Coulombic Efficiency	85.0%	85.0%	85.0%
5 M Cycle Coulombic Efficiency	77.5%	85.9%	85.7%
10 M Cycle Coulombic Efficiency	75.0%	77.5%	77.7%
10 M Cycle Capacity Turnovers	>2,777		
SOC and SOH at 10 M Cycles	71.6% SOC, 87% SOH		

V. CONCLUSIONS

GPU-centric data centers need safe, dual-use energy storage technology options to provide both UPS backup power and AI dynamic power mitigation. This research shows NiZn battery chemistry has the power density, energy density, and cycle life potential to economically achieve the desired dual-use AI system performance. The fast response performance of NiZn, combined with exceptional cycle life and a lack of thermal runaway or fire propagation risks, enables the next generation of large-scale and higher power density energy storage options for AI data centers. The next steps for dual-use NiZn battery AI applications research are:

- Improvement of the NiZn power, response time, and cycle life performance shown in this paper
- Dual-use BBUs with higher power density and lower costs than single-use BBU alternatives
- Dual-use ±400 V and 800 V sidecar cabinets without need for DC-DC converters [5]
- Integration into power electronics to improve system flexibility, cost, and performance

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Figure 2: Cell 50 ms per second Cycle Life IV Curves Table 1: Cell 50 ms per second Cycle Life Performance

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About ZincFive, Inc.

ZincFive is the leader in immediate power solutions for mission-critical infrastructure based on nickel-zinc battery technology. The company's extensively patented nickel-zinc technology delivers high-power, safe, reliable, and sustainable energy storage solutions engineered for the demands of modern data centers, industrial operations, and AI-era infrastructure. ZincFive's systems harness The Power of Good Chemistry® to help customers power what's next without tradeoffs. Headquartered in Oregon, USA, ZincFive serves customers worldwide.

For more information, visit www.zincfive.com

Contact ZincFive

Contact ZincFive today to learn more about its innovative NiZn technology and Immediate Power Solutions (IPS).

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