

Paralleling Flywheels For Power & Reliability Without Limitation: A 750 kVA Flywheel-UPS Demonstration

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Power quality is a major concern for companies whose bottom line is directly linked to continuous operations. Power disturbances dramatically affect the operation of computers, networks, data processing and other microprocessor-based equipment.

Installation of an Uninterruptible Power Supply (UPS) system is a solution that assures the required protection. However, UPS performance depends heavily on the reliability of its integrated energy storage system, which historically has been comprised of lead-acid batteries. The well-documented unreliability of batteries with their high maintenance and hidden operation costs are driving UPS customers to seek battery alternatives.

For the customer in this case study, one of those hidden costs was the cost of floor space (footprint). This customer desired to install several large UPS systems but the space and other costs required for “wet cell” batteries were unacceptable. The change to valve-regulated lead-acid (VRLA) batteries significantly reduced the space requirements but brought unreliability issues. They still needed to reduce the space required for UPS energy storage while holding high reliability.

Because this customer had legal requirements to have “back-up” generators tested and capable of taking over the load in less than 10 seconds during a grid disturbance, they could consider some lower-energy alternatives. Some possible alternatives for consideration included super-conducting magnetic energy storage (SMES), capacitors including “super” capacitors and flywheel energy storage. The customer, having heard about the flywheel energy storage system offered by Liebert Corporation, the Liebert FS, wanted to see the integrated system in operation at the power levels that they required. Consequently, Liebert and Pentadyne Power (the manufacturer of the flywheel system) rapidly assembled a demonstration of the capabilities of the high-power operation of multiple paralleled Liebert FS systems with the 750 kVA UPS that the customer desired.

Overview of Demonstration and Setup

Eight Pentadyne Voltage Support Solution (VSS_{DC}) flywheel power systems (private labeled by Liebert Corporation as the Liebert FS) were integrated with a 750 kVA Liebert 610 UPS. The customer was building new data handling facilities requiring that multiple 750 kVA Liebert 610 UPS systems be installed. However, there were space constraints for wet cell and even VRLA battery systems for the UPS which would be used to “ride through” to the generators during a power interruption. This demonstration showed the customer that the performance of the Liebert 610 UPS with the Liebert FS flywheel power system could meet his requirements for ride-through in a footprint significantly less than even the VRLA alternative. Additionally, the higher reliability of the Liebert FS system compared to that of the battery system meant a higher-reliability UPS system for the customer.

Liebert Corporation (www.liebert.com), a subsidiary of the Emerson Corporation and part of the Emerson Network Power Systems group, is a well-known provider of a wide range of UPS systems with the highest market share of high-power UPS sales in North America. Pentadyne Power Corporation (www.pentadyne.com) with headquarters and production facility in Chatsworth, California, produces a high-speed flywheel power system, the Pentadyne VSS_{DC}, for power quality applications. The Pentadyne VSS_{DC} is private-labeled by Liebert as the Liebert FS through an agreement with Pentadyne.

The Liebert FS / Pentadyne VSS_{DC} is a high-speed carbon-fiber composite system with fully levitating magnetic bearings, an internal vacuum management system, a synchronous reluctance motor-generator and an integrated safety management system. The power conversion electronics, magnetic levitation and motor-generator controls, display/interface panel and disconnect switches are packaged together with the flywheel module in a 25” W x 33” L x 71” H package (Figure 1).

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Figure 1

The demonstration was set-up in a Liebert manufacturing facility in Delaware, Ohio (see Figures 2 and 3).

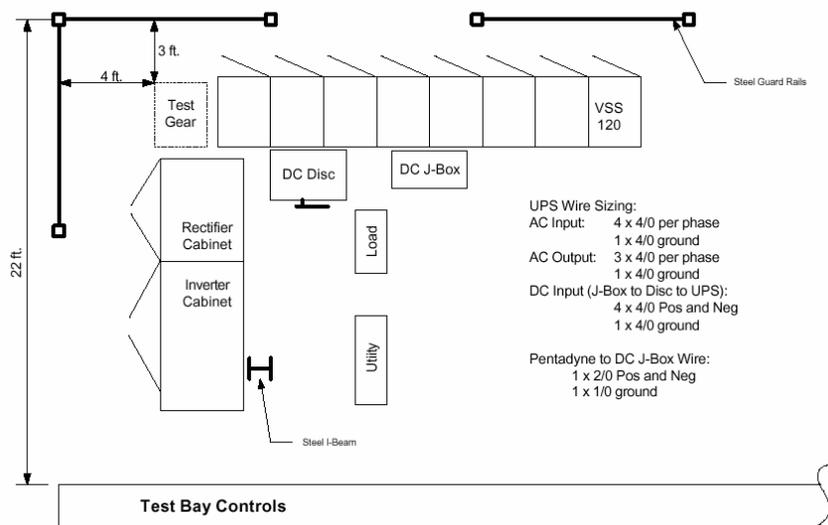


Figure 2

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*Emerson Network Power and Pentadyne
Successfully Demonstrate High-Power Parallel
Operation with the Liebert FS Flywheel Power System*



Figure 3

Demonstration Performance

Eleven different conditions were demonstrated, including:

- Ride-through power interruptions for duration of stored energy at various power levels;
- Loss of one or more flywheel systems during power interruption (discharge);
- Paired sequential discharge at select power level;
- Multiple simulated utility reclosure events; and
- Max supportable power level.

Three conditions are shown below:

- 1) 8 unit ride-through at 720 kW DC bus power (Figure 4);
- 2) A reclosure event followed by a power outage with 1 unit removed during ride-through (Figure 5); and
- 3) Discharge during power outage and sequentially removing 5 units from service (Figure 6).

**672kW UPS Output, 720kW UPS DC Input, 8 Paralleled Units, Full Discharge
Performed at Liebert's Delaware Facility on December 9th, 2004**

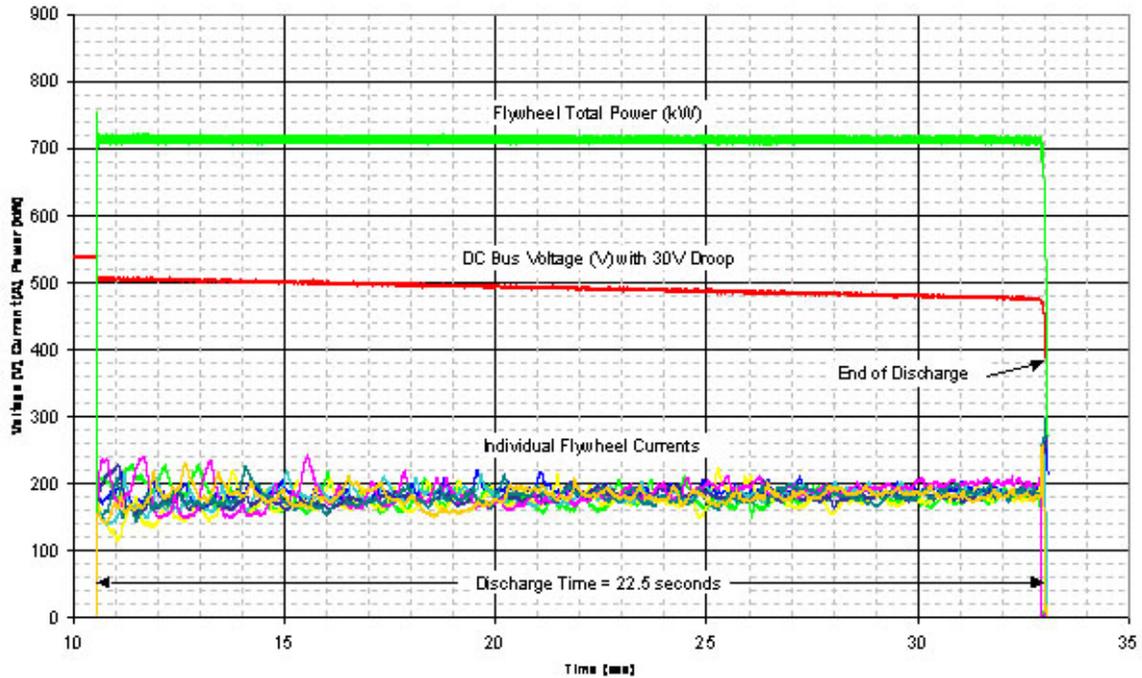


Figure 4

**675kW UPS Output, 720kW UPS DC Input, 8 Paralleled Units, N+1 redundancy
Performed at Liebert's Delaware Facility on December 13th, 2004**

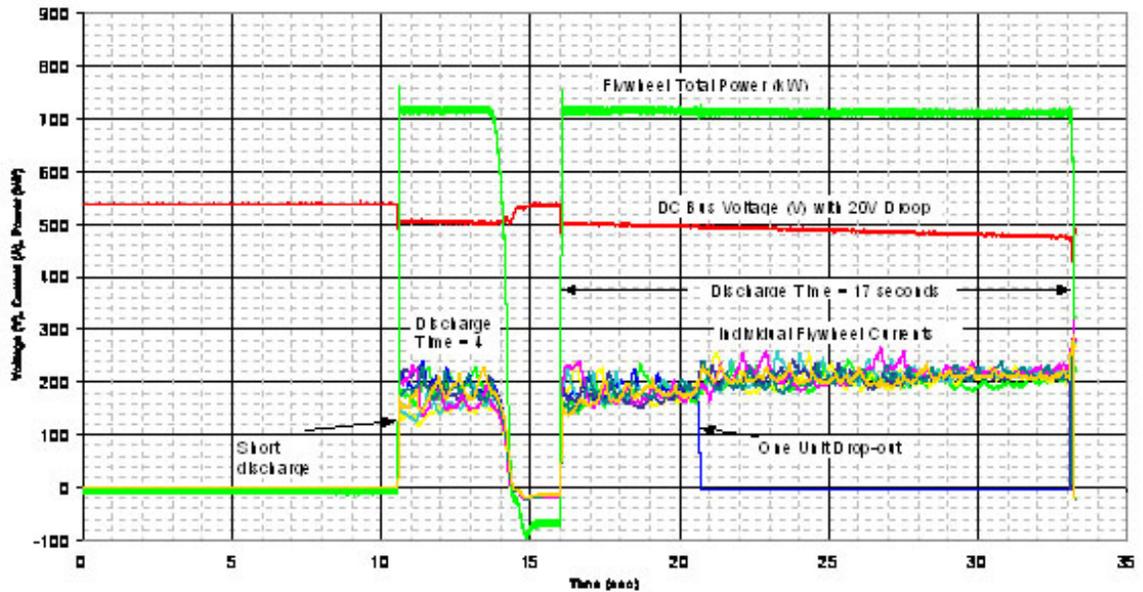


Figure 5

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300kW UPS Output, 320kW UPS DC Input, 8 Paralleled Units, Redundancy Discharges
 Performed at Liebert's Delaware Facility on December 15th, 2004

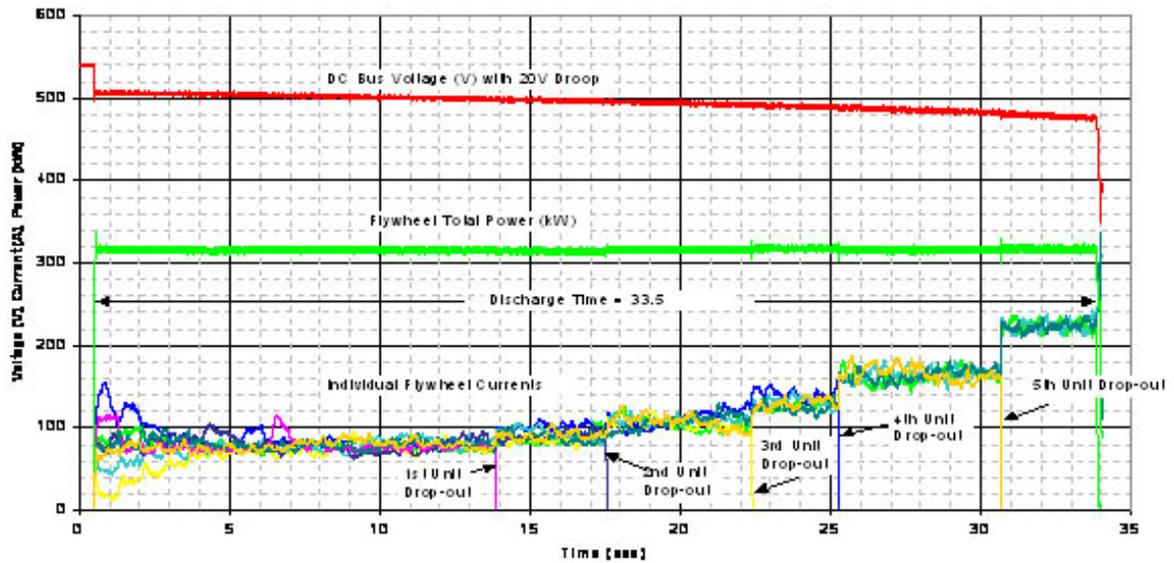


Figure 6



Figure 7 With Pentadyne logo

Observations and Conclusions

- Successful, Stable High Power Operation
 - Customer's UPS load of just over 500kW (540 kW_{DC}) was served with four Liebert FS units;
 - Multi-unit parallel operation was demonstrated feasible to at least 730kW UPS load (790kW flywheel DC load) in this UPS configuration;

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- Loss of flywheel unit during discharges is handled seamlessly provided remaining flywheels are NOT overloaded (planned n+ redundancy);
- Eight parallel Pentadyne VSS_{DC} / Liebert FS systems can serve 1 MVA or more.
- Easy to Set Up the Integrated UPS-Flywheel System
 - Liebert FS flywheel systems were easy to install;
 - Parallel unit setup was easy to accomplish;
 - No external controller is needed for parallel operation;
 - Changes to unit setup/configuration are easy to accomplish.
- Smaller Footprint Than Batteries
 - 4 Liebert FS units => 22.8 ft²
 - 5 Liebert FS units => 28.5 ft²
 - VRLA package (7 min) => 33.7 ft²
 - “wet cell” package (7 min) => 91.7 ft²