



## Hybrid 320 Ton Off Highway Haul Truck: Quarterly Technical Status Report 3, DOE/AL68080-TSR03

This third quarterly status report for the Hybrid Off Highway Vehicle (OHV) project, DOE Award DE-FC04-2002AL68080 presents the project status at the end of June 2003, and covers activities in the third project quarter, April-June 2003.

### Project Management Events

At DOE's request, the program relationship with the mine haul truck builder Komatsu was changed to have Komatsu a subcontractor to GE. Since the scope and value of the Komatsu work was unchanged, the approved overhead costs associated with subcontracts become an additional charge to the contract. To maintain the overall program budget, a proposal for reduction in the program scope was discussed with the DOE contracting officer. The reduction, which will not affect program deliverables, is consistent with the hybrid mine haul truck Energy Storage System concept described in DOE/AL68080-TSR02, the 2<sup>nd</sup> Quarterly Technical Status Report. The reduction comprises the elimination of an ultracapacitor study, and replacement of a nickel-cadmium and nickel metal hydride battery purchase with a less expensive, higher performance sodium-nickel chloride battery system purchase.

A project technical status review has been scheduled with DOE representatives on July 30 2003 at GE Transportation Systems, Erie PA. The first annual report deliverable will be prepared subsequent to the status review.

### Progress in Task 2: "Develop System Specifications"

A highly detailed meeting was held with the sodium-nickel chloride (Na-NiCl<sub>2</sub>) battery system vendor to discuss the hybrid mine haul truck (off highway vehicle OHV) system concept, resulting in the initial sizing of 8 36kWh, 600V systems for the Na-NiCl<sub>2</sub> subsystem, rated for 288kWh capacity. The system will deliver 250kW (another 250kW coming from nickel-cadmium battery bank). GE provided the vendor with a model hybrid OHV operating cycle that will be driven at the Task 8 Demonstration (Fig. 1), and the vendor is carrying out at no charge an ongoing subscale evaluation of the performance of their system operating the GE OHV cycle. The vendor confirmed that the GE OHV cycle will be within the system capability limits, in terms of losses and terminal performance.

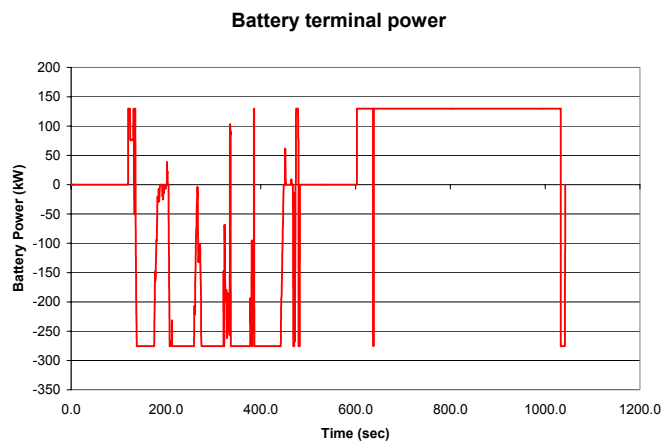


Fig. 1: OHV Uphill Haul Cycle



### Progress in Task 3: “Design and Fabricate Energy Storage System Components”

Design work on fitting the Energy Storage System modules onto the hybrid mine haul truck was initiated. As mentioned in TSR-02, the energy storage modules need to be retrofitted to several locations on the demonstration mine haul truck. Work in the upcoming quarter with truck builder Komatsu will define the locations and attachment concepts.

Detailed effort was initiated to address the Na-NiCl<sub>2</sub> system capability to operate in the haul truck high voltage environment, with respect to maximum terminal voltages, and control connection voltage referencing. Isolation concepts have been developed for the control and low voltage auxiliary supplies, and system protection concept development is ongoing, to ensure that the battery system operates within its voltage rating. An isolated 24V control and fan supply will be provided and the CAN-bus control interface will be optically isolated. Ongoing work will develop a solution to coordinate the ground fault detection systems, coordinate battery box and truck system contactor operation, and develop an appropriate Na-NiCl<sub>2</sub> system voltage referencing to the truck electrical system.

One 18kWh sodium-nickel chloride battery system was furnished by GE (at no cost to the program) for evaluation (Fig. 2). The Hybrid Battery Laboratory carried out a rigorous testing program to verify manufacturer’s specifications and determine internal parameters required for accurate modeling and prediction of hybrid OHV system efficiency and benefits, such as open circuit voltage (see Fig. 3) and internal resistance. Completed tests included commissioning, charge capacity, signature testing, and high power capability; while open circuit voltage characteristic, efficiency, power profile performance, and ripple current performance tests will be completed shortly.

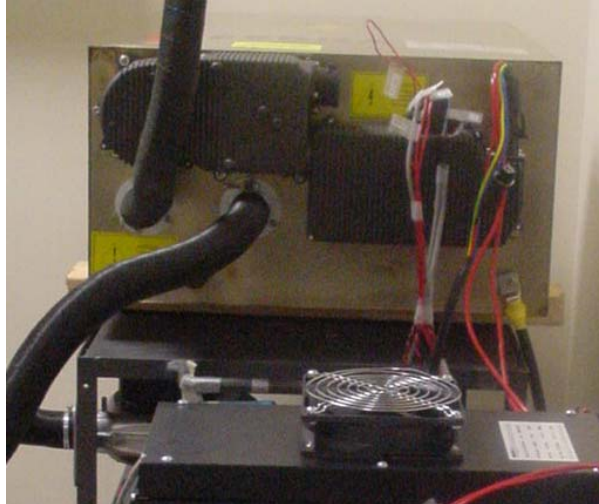


Fig. 2: Na-NiCl<sub>2</sub> battery system under evaluation.

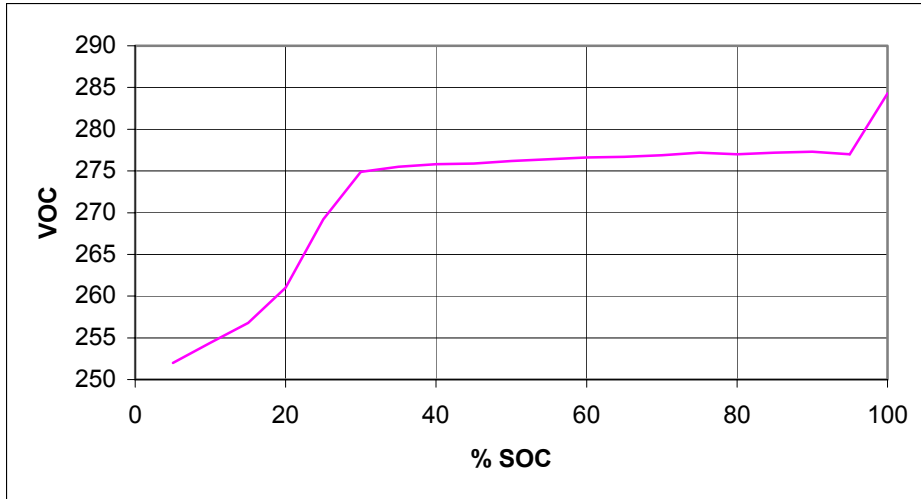


Fig. 3: Sodium-nickel chloride battery open circuit voltage

Another 18kWh battery system was purchased and tested at GE Global Research, NY and forwarded to GE Transportation Systems, Erie PA for risk reduction testing at the building 50A Haul Truck System Test Facility. The risk reduction involves validation of high voltage compatibility before commitment to an order for the full haul truck set of Na-NiCl<sub>2</sub> batteries.

Continuing testing by the Na-NiCl<sub>2</sub> vendor indicates the 288kW-rated energy storage subsystem has adequate cycle life to perform over the whole hybrid mine haul truck demonstration.

### Progress in Task 4: “Design and Fabricate Energy Management System”

The subscale demonstration energy management system protection, performance, and sequencing requirements have been tested in software, and also hardware. In particular, capabilities of power sharing between two energy storage banks, and temperature compensation have been verified. Fig. 4 illustrates control of laboratory battery temperature using the compensation algorithm.

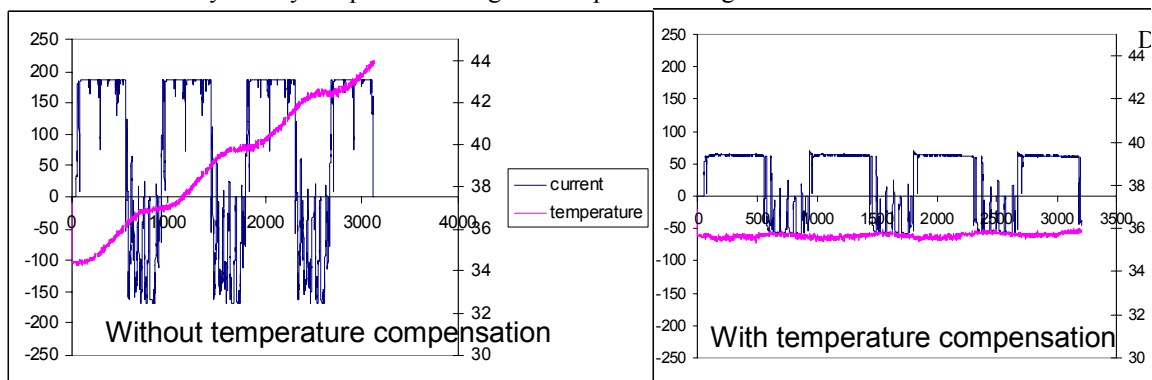


Fig. 4: Battery temperature control



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## **Conclusion**

Energy storage and energy management subsystem development tasks are well in hand and close to completion. They will lead in to Task 5, subscale system evaluation at 100-hp level, in the next quarter. As presented in the kickoff, the project schedule is aligned with completion of the 1<sup>st</sup> project year scope in September 2003. The project team looks forward to the July 30, 2003 project review.