21st Century Locomotive Technology: Quarterly Technical Status Report 24 DOE/AL68284-TSR24

This is the quarterly status report for the 21st Century Locomotive Technology project, DOE Award DE-FC04-2002AL68284. This report covers activities performed October 2008 to December 2008.

Management Events

The GE Battery Technology Symposium was held at GE Global Research, Niskayuna NY on October 22-23, 2008, to explore how batteries are re-shaping the transportation and stationary power sectors. Invited speakers included John Mizroch, Principal Deputy Assistant Secretary, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. Attendees included Christopher Johnson, NETL. Presentations included "Hybrid Locomotive, OHV and Marine Tugs: Hybridization of Industrial Transportation" – Dr Raj Rajiyah, GE Transportation.

Task 3: Hybrid Energy Storage

Subscale advanced sodium battery test results were further analyzed to develop detailed cell electrical characteristics, including resistance and variations with cell temperature. These enable more accurate calculation of hybrid locomotive battery performance under the high power charging and discharging conditions that will be experienced on the locomotive. Updated battery cooling system heat transfer parameters, and cooling fan performance parameters were developed by the battery vendor team (outside this project), and integrated into the hybrid locomotive battery system thermal analysis.

Unfortunately, the subscale advanced sodium battery appears to have sustained internal damage when the battery was moved to a different laboratory location, and further behavioral data can not be generated from this unit. We look forward to analyzing advanced sodium battery performance validation data in 2009, when new batteries will be manufactured.

Task 5: Demonstrate hybrid locomotive concept with full-scale storage modules, and fuel optimizer

Development and refinement of battery thermal management strategies will be an important part of engineering the integration of the advanced sodium batteries into the GE hybrid locomotive. The hybrid battery charge and discharge duty cycles will vary greatly over any particular locomotive mission, and therefore the battery heating due to internal losses will also be highly variable. Like other battery technologies, the sodium battery needs to be maintained within thermal limits to assure long-term performance. Therefore to maximize hybrid battery performance, its thermal management must act to extract excessive losses. However, the application of very high coolant flows demands significant amounts of power which subtracts from the hybrid

system benefits. Development and tuning of cooling strategies seeks to maximize hybrid system benefits while maintaining a low mean parasitic energy loss to operate the thermal management system.

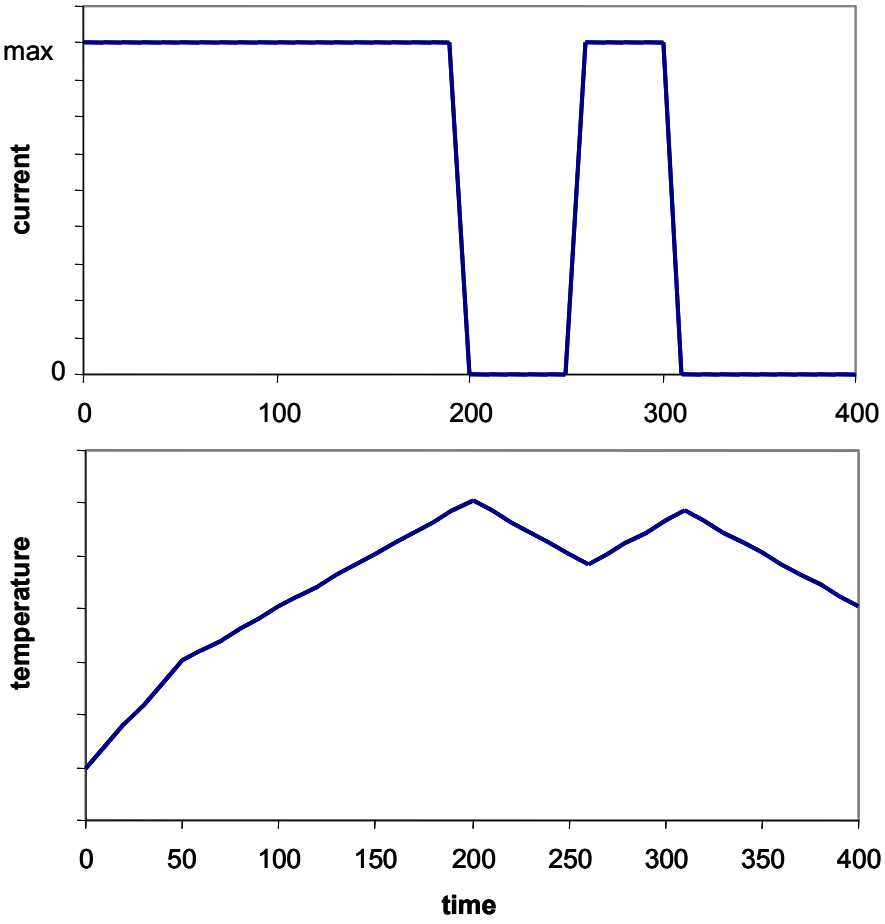

Fig. 1: Example battery thermal event.

An example suboptimal cooling system event is illustrated in Fig. 1 above. The hybrid battery is being charged at its maximum capability, generating significant losses which heat the battery. At t=50 the battery cooling system is triggered, slowing the battery heating rate. Nevertheless, the battery temperature continues rising until at t=200 it reaches the battery maximum operating temperature. At this point, the battery is no longer available for charging until the temperature falls to an acceptable level. At t=250 the battery is re-energized, to capture the last of the available charging until t=300. The unavailability of the battery between 200 and 250 reduces hybrid system benefits.

An approach was developed for the evaluation of hybrid locomotive battery thermal management strategies. The entitlement benchmark will be developed by using linear programmng techniques to optimize cooling modulation to maximize predicted fuel performance for a small number of missions. Subsequently, the performance from realizable control strategies will be compared

against this benchmark. This approach will be used to evaluate thermal management strategies, and also generalized to address charge-discharge strategies.