DEVELOPMENT AND DEMONSTRATION OF AN ELECTRIC SCHOOL BUS

Contractor: Santa Barbara Electric Bus Works, Inc.

Cosponsors: US Department of Transportation Advanced Vehicle Program (Calstart), Bus Works, Los Angeles Department of Water and Power, South Coast Air Quality Management District, Sacramento Municipal Utility District

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Background

Battery-electric power has been identified as having the greatest potential to reduce the emissions attendant to bus operation. Electric buses are also more energy efficient than diesel buses, and because electric-power generation utilized to recharge the batteries is not generally reliant on petroleum fuels, the use of such buses supports a reduction in the national dependency on foreign oil. The recharging of electric buses during off-peak hours also serves to maximize utilization of existing power-generation facilities.

Promising demonstrations of battery-electric technology in school buses were terminated when conventional batteries failed to achieve reasonable longevity or reliability during the 1990s. The most significant obstacles to the widespread adoption of battery-electric school buses were their relatively limited range, perceptions of poor reliability, and relatively high life-cycle costs.

To address these obstacles the Santa Barbara Electric Bus Works developed a medium- and heavy-duty advanced battery electric propulsion system, and converted a Blue Bird TCEV 2000 electric school bus from an unworkable lead-acid battery-electric propulsion system to the advanced sodium-nickel chloride battery-electric propulsion system.

Project Objectives

The project was designed to evaluate the drive system in daily student-transportation service for energy consumption, performance, suitability and reliability.

Technology Description

The ZEBRA sodium-nickel chloride battery technology was chosen for the project application as it had considerable technical merit when compared with the other candidate technologies. Most notable were its reasonable acquisition cost, high gravimetric and volumetric energy densities insensitivity to ambient temperature extremes, and low additional-component count minimizing technical risk in the development effort.

A reiterative design and design-review process examined potential hazards in normal and extraordinary maintenance and operational situations as well as the crashworthiness of the school bus. The sodium-nickel chloride batteries and their battery management system communicate with a stock high-power electric-drive system and achieve new levels of vehicle performance and efficiency using other stock components. The system also uses the drive inverters for battery charging.

Status

Inconsistencies between the vehicle's prototype status and the LA Unified School District's management practices prevented its evaluation there and the bus was moved to Napa for evaluation by the Napa Valley Unified School District, an experienced alternative-fuel user. The electric bus entered service at Napa during the second quarter of 2004. The bus was assigned to regularly scheduled pupil-transportation missions. The bus was operated by one driver on two runs per day, one in the morning and one in the afternoon. The two runs were each approximately 34 miles long and were each completed in a little over one and one-half hours. Occasionally the bus was utilized for field trips.

The demonstration/evaluation project was completed in July 2005. The final report is on file with complete technical details of the project.

Results

Vehicle performance is comparable to conventionally powered school buses of similar size. Reliability of the bus has been better than that of any other electric school bus yet placed in service. All issues preventing regular dispatch of the bus have been corrected as encountered and may be largely attributed to its prototype status. A number of these problems were related to the conversion of an existing (used) bus for the prototyping effort and would likely not be encountered in a production vehicle. Maintenance on the prototype bus is simpler than on a conventionally-powered bus. There is no regularly scheduled powertrain maintenance other than inspection to verify the integrity of cabling and the cooling system.

The normal duty cycle of the bus yields an average speed of less than 20 mph and about 25% stationary time. Speeds to 45-55 mph are achieved for short distances on the bus' routes. Normally encountered road gradients range from ± 1-6% and occasional hills with ±8-12% gradients are encountered in the daily runs. Top speed is 62 mph and gradability is 15% at over 15 mph. The bus has exhibited comfortable margins of both power and energy.

Grid energy consumption in service averaged about 1.28 kWh/mile. Traction energy consumption averages 1.44 kWh/mi for driving and accelerating, and regenerative braking returns about 0.36 kWh/mile, giving a net energy consumption of 1.09 kWh per mile. Battery energy efficiency during operation averaged 84%.

Regenerative braking energy amounts to 25% of the traction energy expended and results in a range extension of almost 22%. Unrecharged range of the bus is from 60 to 70 miles depending on driver skills, average speeds and gradients, and passenger loads.

Two of the batteries were experiencing problems at the end of the evaluation period. The problems resulted from battery inactivity during the two-year stay at Los Angeles Unified School District but were corrected by the manufacturer. The bus continues in service with the Napa Valley Unified School District and has completed more than 450 operational runs. It is now dispatched on two daily runs of approximately 50 miles each.

Benefits

The pupil-transportation mission is a nearly ideal scenario for deployment of battery-electric vehicles. Centralized maintenance, close supervision of highly trained drivers, and a number of ideal routes all contributed to the success of this demonstration project. Total regulated emissions are approximately 9% of a 1998 diesel with catalytic converter and local NOx reductions of 94% or 660 pounds per year are realized on an 18,900-mile duty cycle. Replacement of 3,000 pre-2000 30-foot diesel school buses in the South Coast Air Basin (estimated 100% market penetration) would result in an annual NOx reduction well in excess of 1,000 tons. Incremental costs in excess of $18,000 per ton of avoided NOx emissions are foreseen but total project cost is prohibitive. No additional adverse environmental impacts are likely.

Project Costs

A total of $717,130 was spent on this project with funding provided by the following sponsors: USDOT/Calstart ($322,148), Bus Works ($138,006), LADWP ($106,976), SCAQMD ($100,000), and SMUD ($50,000). Although project costs were significantly higher than the originally projected $400,000 because of modified work scope and project delays, the additional costs were fully borne by USDOT, Bus Works, and SMUD, with no additional funding required from SCAQMD.

Commercialization and Applications

Commercialization of the technology for school-bus use is not anticipated because the substantially higher vehicle cost is beyond the reach of most school transportation budgets. However, the technology is appropriate for replacement of 40%-60% of diesel and CNG transit bus fleets of 30-foot class transit buses. The technology is now ready for commercial use pending integration into specific platforms.

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