ThunderVolt™ hybrid-electric buses

by Bill Siuru, Jr., PhD, PE

Two California cities are getting these advanced technology transit buses.

Hybrid-electric vehicles (HEV) overcome the two main disadvantages of pure electric-powered vehicles — limited range between recharges and extended times needed to recharge battery packs.



ISE Research TB30H hybrid electric bus in operation with LADOT in downtown Los Angeles.

The Los Angeles Department of Transportation (LADOT) is operating four hybrid-electric buses on its Lincoln Heights-Chinatown route in downtown Los Angeles. These 30-foot-long transit buses feature ThunderVolt™ TB30H hybrid-electric drive systems developed and built by ISE Research Corp. (San Diego, California). The first unit, which began service in March of 1999, has accumulated nearly 10,000 miles. ISE Research is on contract to deliver four more TB30H buses by the middle of next year.

The buses use an ElDorado National RE-29 bus chassis and body built at the ElDorado factory in Chino, California. ISE Research then adds its versatile ThunderVolt drive system, which has been used in a variety of applications from airport tow tractors to Class 8 heavy-duty trucks. While the specifics of the ThunderVolt system vary according to the specific requirements of the application, the basic layout includes an electric motive drive, batteries for energy storage, ICE auxiliary power unit (APU), a control system and electrically-driven accessories.

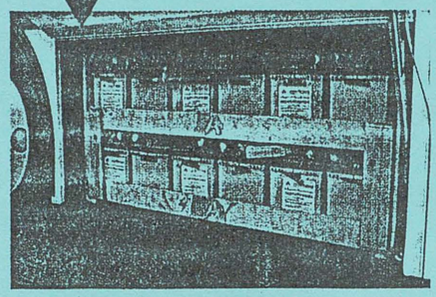
By adding a relatively small internal combustion engine (ICE), range can now be greatly increased since batteries can be charged while the bus is traveling along its route. When a hybrid electric bus is running only on its batteries, it is a zero emissions vehicle (ZEV). And even with the engine operating, it still produces very low emissions.

In the LADOT buses, the motive drive system uses a Siemens AC induction motor driving the rear wheels via a two-speed gear reduction system. The air-cooled electric has a peak power output of 140 kW (190 hp), 100 kW (136 hp) continuous power, maximum speed of 5,000 rpm and an efficiency of 94 percent. This motor was originally developed by Siemens for heavy industrial machinery. More powerful motors, up to 400 kW (528 hp) are available. For example, ISE is now building 40-foot ThunderVolt TB40H hybrid-electric buses featuring New Flyer bodies and chassis that will be used in San Bernardino starting in the year 2000. The San Bernardino buses will use two different types of motors. Two will use Siemens motors rated at 190 kW continuous (250 hp). The third bus will use an upgraded version of an experimental high power motor licensed from United Defense, LP, which has a continuous power rating of 388 kW (512 hp), which exceeds the requirements of just about every vehicle on the road today.

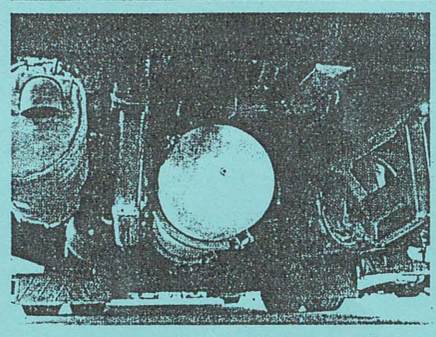
The TB30H bus uses 48 inexpensive, sealed, maintenance-free, lead-acid batteries. More expensive, advanced technology nickel-metal-hydrid (NiMH) or lithium (Li) batteries could be substituted.

The ThunderVolt system's auxiliary power unit operates in a "load following" mode to supply most of the vehicle's energy needs as it moves along its

ThunderVolt™ Hybrid-Electric Buses



Battery pack of 12 volt lead acid batteries. The bus uses a total of 48 batteries.



Propane tank under the bus.

route. The battery pack only has to supplement the APU's internal combustion engine for brief periods, mainly for acceleration and hill climbing. Therefore, this ICE is normally sized to meet the vehicle's average power requirements. For example, over the course of a typical 30-foot bus' driving cycle, the bus obtains about 300 kilowatt hours of energy from the APU and, at most, about 20 kilowatt hours from the battery pack. The battery pack enables a major reduction in the size of the ICE.

This series hybrid configuration offers maximum benefits in vehicles that do lots of stop and go driving, and have lower average power requirements. The bottom line is lower fuel consumption and less emissions because the engine can be smaller than required in traditional diesel-engined buses of the same size.

The four LADOT buses use the same General Motors 5.7 liter V-8 used in Chevrolet and GMC pickups and SUVs like the Tahoe and Yukon. However, the engine has been modified to operate on clean burning propane. Other fuels such as gasoline, liquefied natural gas (LNG) or compressed natural gas (CNG) could also be used.. The larger TB40H buses being built for use in San Bernardino will use the ultra-low-emissions Ford V-10 truck engine running on gasoline. Another option is the popular Cummins 5.9-liter engine operating on diesel or natural gas. The Microturbine from Capstone Turbine Corp. (Tarzana, California) operating on natural gas or other fuels could also be substituted. Indeed, the four additional LADOT TB30H buses will use Capstone microturbines.

A sophisticated onboard computer network continuously monitors vehicle power and battery levels, then controls the power output of the battery pack to provide just the right amount of power to augment the APU for acceleration and hill climbing. The TB30H can accelerate to 30 mph in 10 seconds or to 55 mph in 38 seconds. By adjusting the motor selection and gearing, virtually any top speed can be accommodated. The current LADOT buses can only travel about 50 mph, but could be set up for higher speeds up to 65 mph. The range of the TB30H depends on the size and number of propane tanks installed. With the standard 63-gallon tank, LADOT buses can travel about 185 miles between refills, though the requirement is only 150 miles. The TB40H drive system designed for larger 40-foot buses could have operating ranges up to 400 miles depending on the type of fuel and tank capacity.

The APU could be turned off and the bus now operates as a zero emissions vehicle. Therefore, without the APU running, the bus can satisfy any zero-emission regulations such as might be required in pollution-free urban centers. This is possible because all accessories, including the air conditioning, are electrically driven off the battery and are completely decoupled from the APU. The ThunderVolt system features electro-hydraulic power steering and electro-pneumatic air brakes with regenerative braking. With regenerative braking the electric motor operates as a generator to convert deceleration and braking energy to electricity to help keep the batteries charged and add to the range. According to ISE Research, the TB30H system is rugged enough to give a 10 to 12 year life when operating on demanding urban routes such as in downtown Los Angeles. The company says the prices for the buses now start at just under $370,000, but expect prices to drop significantly over the next year or so with greater volume production. The ThunderVolt system can be used in buses weighing up to 65,000 pounds, which is the estimated weight of a 60-foot articulated bus using this drive system. Indeed, ISE Research is now demonstrating a ThunderVolt powered Class 8 truck with an overall vehicle weight of 80,000 pounds. Class 8 truck ICEs would typically use Cummins 5.9-liter or John Deere 6.8-liter engines for the APU — both heavy duty rated, but somewhat smaller than would be typically used in a large Class 8 vehicle.

Drivers for Ryder/ATE, the LADOT contractor operating the ISE Research hybrid-electric bus, say the performance is "superb," and cautioned each other to exercise care when driving, because of the vehicle's unusually fast acceleration. The hybrid-electric bus is also able to climb hills that cannot be handled by equivalent diesel or compressed natural gas buses. ■