Hybrids for commerce

Though they represent a fraction of the Japanese hybrid fleet, the four Japanese commercial-vehicle manufacturers offer diesel-electric hybrid trucks and buses that are on the leading edge of the technology.

by Jack Yamaguchi

Among Japan's in-use vehicle population of about 74.7 million units in 2004, hybrids accounted for 196,000, according to Japan Automobile Manufacturers Association (JAMA) statistics. They are largely passenger cars, and mostly three generations of Toyota's Prius, with Honda's two generations of Civic Hybrid occupying the honourable yet distant runner-up position. The hybrid's growth is nonetheless phenomenal, from 1996's mere 200 vehicles, to 3700 in the following year when the first-generation Prius was launched, to 50,400 in 2000, and now reaching a quarter of a million.

The percentage of hybrid commercial vehicles is even smaller. JAMA cites “2004 FY shipments” of 1209 trucks and 35 busses, indeed sake-cup-size drops in the 550,000 and 18,000 unit lakes—if not seas—respectively. Yet the four Japanese commercial-vehicle manufacturers—Hino, Isuzu, Nissan Diesel, and Mitsubishi Fuso—all offer diesel-electric hybrids.

A significant price premium

Large numbers of light- and medium-duty diesel trucks are used in Japan for urban and suburban delivery duties with frequent stop-and-go driving. Combining the two efficient power sources, diesel engine and electric motor, is certainly attractive for greatly improving fuel efficiency, thus decreasing CO₂ emissions as well as reducing tail-pipe pollutants. It is a very effective silver bullet but inevitably carries a price. Nissan has recently added a medium-size diesel-electric hybrid to its Atlas 20 range, which is OEM-supplied by Isuzu. All Atlas 20 hybrid models are priced at 1.28 million yen (about $11,300 at 1¥/115 rate) higher than comparable diesel models, the base diesel-hybrid 2.0-ton (1.8-t) van chassis carrying a price tag of ¥4.95 million ($41,700).

There are tax concessions and incentives granted on “green vehicles,” as well as improved fuel economy; however, private, corporate, and municipal fleet operators are more often motivated by “eco-correctness,” adding diesel-electric hybrids to their vehicle fleets for social reasons.

Japanese light- and medium-duty trucks are invariably the cab-over type, with the powertrain, placed under the cab and seats to maximize volume, driving the rear wheels. Diesel-electric hybrids from the four manufacturers are all parallel hybrid types, with the powertrain and ancillary components fitting under the cab and truck bed.

Two ranges from Hino

Hino, a member of the Toyota group, companies specializing in commercial vehicles, makes the Dutro Hybrid, the smaller truck of Hino's two hybrid series. The base model measures 4640 mm (182.6 in) long and 1695 mm (66.7 in) wide on a 2525-mm (99.3 in) wheelbase, but there are longer and wider models in the series.

The Dutro Hybrid's engine is a common-rail inline four-cylinder diesel employing a variable-nozzle turbocharger, intercooler, and cooled EGR. It produces 110 kW (148 hp) at 3000 rpm from 4009-cm³ displacement and is equipped with Hino's single-stage particle-reducing (DFPR) cleaner, which collects as much as 95% of the soot produced and burns it off when accumulated. The Dutro Hybrid is certified as an ultra-low-emissions vehicle, earning four stars in the particulate matter category. The phase-ac synchronous motor/generator rated at 23 kW is positioned inline between the engine and a manual five-speed transmission. The engine and motor produce a combined torque of 392 N m (292 lb ft) at 1600 rpm.

The truck's primary motive power is its diesel engine assisted by the motor/generator on launch and acceleration.
Isuzu offers a diesel-electric hybrid version of its Elf small truck series.

Nissan Diesel chose supercapacitors for its Condor medium-duty truck because of their inherent robustness.

Nissan Diesel produces supercapacitors for vehicular and industrial uses.

Carlos Ghosn, outsourcee the Atlas 20 medium-duty hybrid truck from Isuzu, as it does with various vehicle models from other manufacturers to supplement its own lineup to fill niches.

ND launched its Condor Capacitor Hybrid medium-duty truck in 2002. In 1996, the company began its diesel-electric hybrid research employing capacitors rather than batteries for secondary electrical energy storage. ND joined the ACE (Advanced Clean Energy) Vehicle project of the New Energy and Industrial Technology Development Organization (NEDO) in 1997. In the same year, ND entered a technology assistance contract with Akamn Laboratory, which is now consolidated with Power Systems and carries the latter's corporate name: Power Systems is a specialist in production and sale of electric double-layer capacitors, also called electrochemical capacitors, ultracapacitors, and in ND's application Super Power Capacitors.

ND revealed a prototype CNG-fueled ICE-electric hybrid bus employing its Capacitor Hybrid concept in 2000, and launched the Condor Capacitor Hybrid diesel-electric truck two years later. The company installed its own Super Power Capacitor production facility at the Ageo factory complex in Japan, producing capacitors for vehicular and industrial uses.

The Super Power Capacitor cell is a laminated type, comprising two layers of propylene-polypropylene, electrolyte-imregnated activated carbon electrode, sandwiched between aluminum collector plates and separated by a separator plate. In the truck application, the Super Power Capacitor module consists of 284 cells, each putting out a maximum 2.7 V and 1500 F, for module outputs of 346 V and 583 W, respectively. A recharge control device is integrated within the module.

A typical diesel delivery vehicle's life extends beyond 600,000 km (370,000 mi), versus a passenger car's 150,000-200,000 km (93,000-124,000 mi), according to ND. With frequent stop/start repetitions, the diesel-electric hybrid would incur over 2.4 million regenerative braking applications, versus 600,000-900,000 of a hybrid passenger car. Reliability and longevity of the secondary energy-storage system is therefore of
utmost importance, insists ND. The capacitor, a physical storage device versus chemical batteries, is inherently robust. Its weakness is a power density inferior to latest battery types such as Ni-MH and Li-ion; however, ND has improved its capacitor’s output greatly through material selection and development to a competitive 6.3 W·h/kg. Among the Super Power Capacitor’s strengths are its superior discharge/recharge efficiencies.

The Condor Capacitor Hybrid is a medium-duty truck, a typical standard-length van measuring 8000 mm (315.0 in) long and 2205 mm (86.9 in) wide on a 4380-mm (172.4 in) wheelbase. It is powered by an inline six-cylinder diesel displacing 6925 cm³ and rated at 152 kW (204 hp) at 3000 rpm and 500 N·m (369 lb·ft) at 1400 rpm, with a permanent-magnet ac synchronous motor providing 55 kW and 130 N·m (96 lb·ft) output. Drive is through an electronically controlled mechanical six-speed transmission connected to the rear wheels. The transmission retains a foot-operated clutch pedal, although it may operate in fully automatic mode. The motor is positioned outrigger-style, driven via a short shaft and gearbox.

The Condor Capacitor Hybrid starts off on electric power in the transmission’s automatic mode. The driver may start off using engine power by disengaging/engaging the clutch pedal as in a conventional manual transmission.

ND claims fuel economy is 1.5 times that of a comparable diesel model in the Japanese M15 test cycle mode, with NOx and PM reduced by 44% and 66%, respectively.

Long history for Mitsubishi

Mitsubishi Fuso, now a member of the DaimlerChrysler commercial vehicle group, has a diesel hybrid history that stretches back to 1992, when a fleet of its MBECs (Mitsubishi Brake Energy Conservation System) city buses entered regular service in the city of Yokohama. MBECs employed a hydraulic pump/motor that called upon regenerated energy from an accumulator to assist the diesel.

In a 2002 limited trial, a fleet of Mitsubishi Fuso diesel-electric hybrid buses served to transport spectators at World Cup Soccer games held in Japan. Two years later, the company launched a commercial version of the Aero Non-step HEV series-hybrid bus. An 8.2-L diesel engine is employed to drive an ac permanent-magnet 43-kW generator to charge a 612 V Li-ion battery pack positioned on the bus’s roof. The battery supplies electrical energy to twin ac induction motors of 90-kW output, each driving the rear wheels. An additional motor drives vehicle ancillaries.

Mitsubishi Fuso’s latest offering is the Canter Eco Hybrid light-duty truck. The diesel engine is a four-valves-per-cylinder turbocharged and intercooled inline four-cylinder unit of 297 cm³ producing 92 kW (123 hp) and 294 N·m (217 lb-ft). It is combined with a liquid-cooled, permanent-magnet synchronous motor/generator of 35 kW and 200 N·m (148 lb-ft) positioned between the automatically operated friction clutch and electrically shifting mechanical transmission called INOMATIII. The secondary energy storage system is a Li-ion battery module with 48 cylindrical cells, each having 5.5 Ah capacity and 3.6 V for total power of 43.2 kW, 0.95 kW/h of energy capacity, and 172.8 V. The module, which measures 508 x 278 x 107 mm (20 x 10.9 x 4.2 in) and has a mass of 18 kg (40 lb), is mounted on the outer chassis frame under the truck bed.

While the engine is turned on for a system check, the vehicle moves off on electric power. The clutch is then automatically engaged, and the engine drives the vehicle with motor assistance in the low- and mid-rpm zone to optimize fuel economy. The motor/generator improves driveability, especially of the automated gearshift, by synchronizing system speeds. The engine clutch is automatically disengaged on deceleration to maximize the motor/generator’s regenerative ability. Coming to a halt, the lever to the N position automatically stops the engine, which restarts when the lever is moved to

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