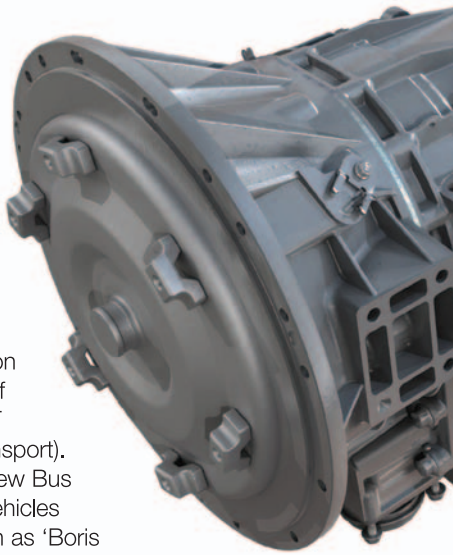
Three-horse

As diesel-electric hybrid buses move beyond trials and into the mainstream, new diesel-mechanical (flywheel) hybrids are offering another way. Time to reassess, writes Brian Tinham

Back in July, TfL (Transport for London) celebrated the arrival of its 300th diesel-electric hybrid bus. Last month, Lothian Buses announced that Scotland's fleet of 15 double-decker hybrids had been serving Edinburgh for one year – all Alexander-Dennis (ADL) Enviro 400s (with BAE Systems' HybriDrive). In April, that same operator had also confirmed an order for 10 Volvo 7900 hybrid single-deckers, with start-stop technology.

In March, Stagecoach confirmed orders for 59 hybrids – 40 for Manchester and 19 for Sheffield, all also ADL Enviro 400s. When they're delivered, they will add to this operator's existing fleet of 123 hybrid buses and coaches already running across its regional network. And so the list goes on. The point: hybrid buses are well beyond trials and on their way to maturity. Or are they?

Returning to London, which started hybrid bus operations back in 2006 (then with Wrightbus Electrocity single-deckers, followed by double-deckers), we're certainly not talking about a single bus supplier. Nor is the technology behind TfL's hybrids anything like identical. The capital's fleet currently comprises 180 ADL vehicles, 77 Volvos, 32 from Wrightbus and 11 from Optare. And although the majority are 'series' type hybrids, its Volvo and Optare vehicles rely on 'parallel' drivetrains (see panel).



TfL also has a further 104 hybrid buses on order from ADL and Volvo, following the provision of £5 million worth of funding from the DfT (Department for Transport). And a further 600 New Bus for London (NBfL) vehicles (affectionately known as 'Boris Buses' and being manufactured by Wrightbus) should be arriving over the next four years. These hop-on, hop-off units – seven of which are already in service with Arriva – also harness series hybrid technology, but with Cummins' diesel and Siemens' electrics.

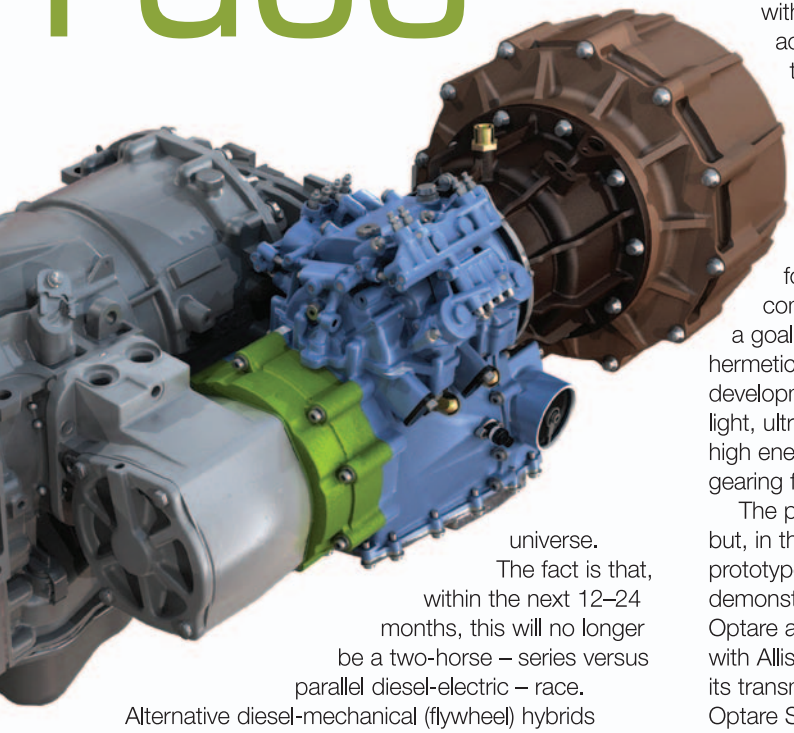
Boris Johnson: making the point that more than 1,000 hybrid buses will be on London's streets by 2016

Time to rethink?

London Mayor Boris Johnson is fond of making the point that, as a result, more than 1,000 hybrid buses will be on the capital's streets by 2016. More to the point, the existing fleet is notching up 30% fuel savings, against modern diesel equivalents, as well as reducing operational costs, according to London Buses operations director Mike Weston. "Operator confidence in hybrids has increased immensely, which, alongside reductions in the capital premiums and increasing [diesel] fuel prices, is making this technology increasingly attractive," he reports.

But, all that being the case, it's time to review the technology choices for hybrids. This is not just about fleet managers making properly informed choices – and workshops, too, being briefed on what's coming. Of course, both need to understand the pros and cons of the latest diesel-electric variants and their suppliers. But, just as important, they also need to be aware that there is another, very different, rising star for buses and coaches in the hybrid

race



universe.

The fact is that, within the next 12–24 months, this will no longer be a two-horse – series versus parallel diesel-electric – race. Alternative diesel-mechanical (flywheel) hybrids should by then be in operator fleet trials ahead of full production – and these could be game changers. Because not only do they promise capital costs at just one-fifth of diesel-electrics; they also may well be retrofittable to vast numbers of existing conventional diesel vehicles, offering the prospect of cutting fuel consumption and carbon emissions by up to 20%.

Cast your mind back a few years, and you'll remember the introduction of superfast flywheels for dynamic energy storage in Formula One. As John Fuller, product director for MKERS (mechanical kinetic energy recovery systems) at novel traction drives specialist Torotrak, says, the initiative then was promoting green technology to the automotive and on-highway vehicles sector.

Small, but powerful

It worked, and not long afterwards the government-funded FHSPV (flywheel system for premium vehicles) project, led by Jaguar Land Rover, got underway. That harnessed the Flybrid flywheel system controlled by Torotrak's compact CVT (continuously variable transmission) technology. The project's goal was to demonstrate the potential for fuel saving with flywheels on luxury cars, by storing and releasing braking energy to supplement traction, automatically.

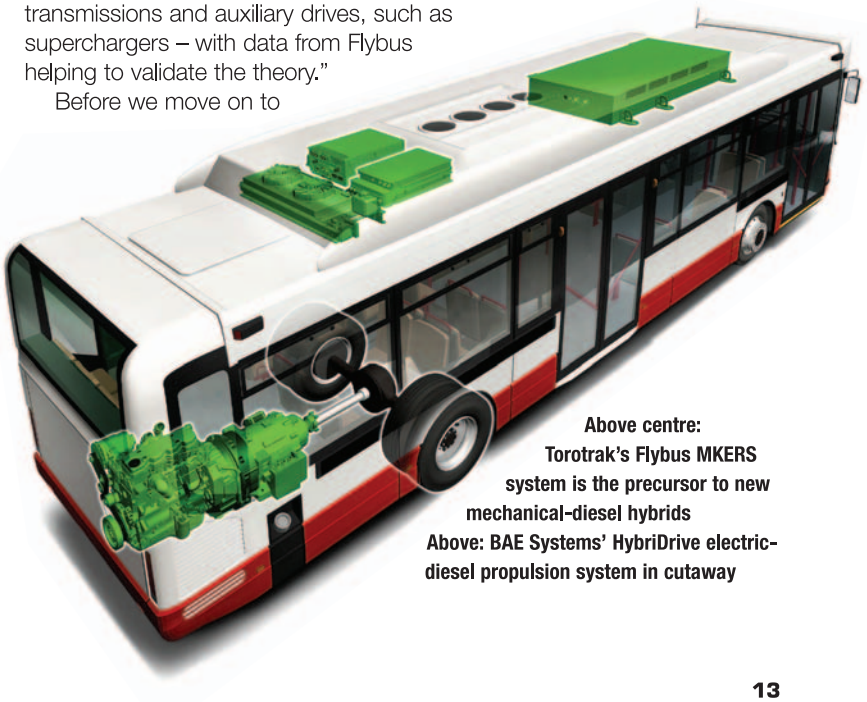
Why the CVT? Because it offers excellent, but, more importantly, direct torque control, as well as high power density. Fuller explains that its seamless gearing means the hybrid powertrain delivers torque in the same way as the engine, adding to or subtracting from engine output very responsively, following driver demand. Compare that to working with conventional stepped gear ratios during acceleration and deceleration cycles, where the flywheel controller would need to manage an additional, and potentially conflicting, complication.

"That project delivered a 22% fuel economy benefit over the Artemis European drive cycle," recalls Fuller. However, Ricardo's KinerStor programme followed, aimed at cost-cutting and commoditising flywheel hybrid technology, with a goal of moving towards production. Ricardo's hermetically-sealed, magnetically coupled flywheel development was key here, capitalising on the small, light, ultra-high speed approach that leads to such high energy density, and its magnetic step-up gearing for flywheel speed magnification.

The programme completed in March this year, but, in the meantime, the much publicised Flybus prototype flywheel hybrid–based city bus demonstrator was also gaining momentum. Ricardo, Optare and Torotrak were the consortium members, with Allison in the picture, providing support around its transmissions. The vehicle converted was an Optare Solo midibus, and the entire flywheel and CVT arrangement was mounted on the existing Allison PTO (power take-off), with control integrated into the transmission.

"There are no further plans for the Flybus vehicle itself," states Fuller, "but it provided a multitude of learning points that we are now taking forward into the next stage of development, again with Optare. We've built a very comprehensive CAE (computer aided engineering) simulation toolkit for MKERS, transmissions and auxiliary drives, such as superchargers – with data from Flybus helping to validate the theory."

Before we move on to



Above centre: Torotrak's Flybus MKERS system is the precursor to new mechanical-diesel hybrids
Above: BAE Systems' HybriDrive electric-diesel propulsion system in cutaway

the future, note that Flybus used Allison's standard gearbox PTO. Hence the potential for adding mechanical KERS to existing buses. "Using the existing hardware infrastructure means that this mechanical hybrid technology is ripe for retrofit, using a relatively simple bolt-on assembly," explains Fuller. "That's a huge market."

Options and trade-offs

But that's not all. For the next phase, he states that the Flybus KERS arrangement was one of several different architectures, so Torotrak will be using its simulation software to optimise designs for different vehicles, transmissions, operating conditions and duty cycles. Options might include: installing the system onto the engine, rather than the turbine side of the torque converter (as per Flybus); or closer to the axle and wheels, on the drive shaft.

There are trade-offs. The former could enable use of the flywheel over a wider speed range through the gearbox, although power from the wheels would have to travel a more tortuous path. But, while the alternative axle-based architecture means better 'round trip' energy efficiency, it may not allow use of the flywheel through as much of its envelope.

Either way, Torotrak and Optare are now moving inexorably towards fleet trials with a diesel-mechanical hybrid that requires very few vehicle modifications, appears robust, and involves none of the costs associated with batteries and power electronics. "The results from first-stage prototype investigation have created enough interest from potential customers for us to take the lead with the development of a production-representative system," declares Torotrak's new CEO Jeremy Deering. "We hope to have the new system running in a little over 12 months. This is looking like a commercially very attractive system that offers operators substantial fuel savings, without the cost, weight and other issues associated with battery-based technologies."

Clearly, bus operators can look forward to cheap, efficient, flexible mechanical hybrid technology, available for retrofitting and diesel engine re-optimisation on new buses and coaches. Yes, the environmental and fuel benefits are not quite in the 30% range recorded by diesel-electrics, but the return on investment is far more rapid and, for many, far more realistic. Further, Torotrak's Fuller suggests that the technology need not be restricted to midibuses and could easily scale up. TE

Series versus parallel hybrid electrics

Diesel-electric hybrids split into 'parallel' and 'series'. Parallel hybrids – in which an electric motor provides torque assistance to the diesel engine on demand – are the best choice for long-haul, high-power, extra-urban duty. As Phil Stones, manager of vehicle emissions and fuel economy at Millbrook Proving Ground, says: "They're efficient, because power drives straight through the drivetrain to the wheels, without additional losses."

Main variants are around the detail of operation and engine size. "The electric drive can be used to pull away and run the bus at low speed, with the diesel cutting in for higher-power, higher-speed work. Or the engine can run all the time, with the electrics providing an assist for acceleration, using the power from KERS [kinetic energy recovery system]," he explains.

Hence the move for smaller diesel engines, with some manufacturers favouring lower-power heavy duty, while others move toward light duty engines from the likes of Ford and GM. "Most are going to the lighter end of heavy, because they're more durable and bus operators are more used to them."

As for series hybrids – in which the diesel engine acts only as a generator, charging the batteries that, in turn, power the electric motor(s) – these are the best choice for stop-start, return-to-base operations. Stones points out that energy efficiency is compromised, because of the number of conversions to get power to the wheels. "On the other hand, there is no transmission to worry about and the diesel engine can run at its most efficient operating point," he adds.

For developer BAE Systems, which offers parallel and series versions of its HybriDrive, one of the strengths of the latter is its potential to evolve into an electric-only traction system. As Rob Lindsay, director of OEM accounts at BAE Systems, puts

it: "Series hybrids are electric buses with diesel generators. As battery technology improves, we can downsize the diesel generator, or maybe use in-road induction charging or overhead lines, to supplement the charge."

Looking at series variants, they are principally multi- or single-electric motor. There are two main versions of the former: one involving axle-mounted motors for each driven wheel, meaning they're close to the drive point, but have to contend with suspension movement; the other a cost-down approach, using off-the-shelf electric motors and a gearbox.

"We don't believe either is the right choice," comments Lindsay. "With a single, purpose-built induction motor, bus operators get the maintenance advantage of a very simple mechanical arrangement and no transmission. So it's very reliable, and the system is designed for the size and weight of the vehicle. Percentages count in electric hybrids and this approach is very efficient."