RQ CLEAN ENERGY

DELIVERING the goods

Intelligent Energy, as the leader of a consortium to design a range-extended electric delivery van, called upon Ricardo's expertise in simulation, powertrain control and telematics. **Farah Alkhalisi** looks at the t-001 RE-EV demonstrator vehicles and talks to the team involved in this project

Leading power technology company Intelligent Energy, working in partnership with Revolve Technologies, was recently successful in gaining funding assistance from the UK government's Technology Strategy Board (TSB) for a project to develop a lightweight and ultra-low emissions delivery van. The project team, led by Intelligent Energy's low emissions vans subsidiary IE LEV, submitted a proposal for a range-extended electric van (RE-EV) aimed at the fleet vehicle market, featuring a diesel engine acting as an auxiliary power unit (APU). To develop the proof of concept the team turned to Ricardo.

"One of the things Ricardo did very early on in the simulation work was to confirm that the specification for the components was the right choice," explains IE LEV's's programme director Chris Hiett. "In February 2011 we signed a contract with Ricardo, and at that stage, we had already identified the diesel engine, battery, motor and generator and inverter suppliers contributing to the project. However, we did not have the exact specifications. Ricardo's technical activities and strengths and their knowledge of electric vehicles and EV drivelines, made us confident in their ability to do the simulation work."

Ricardo was subcontracted for the simulation and also to develop and supply the vehicle control system, which has now been fitted into two prototype demonstrator vehicles built by Revolve.

Driveline details

The t-001 features a 25 kWh lithium-ion battery with a 75 kW traction motor and a Ford four-cylinder, 1.4 litre diesel engine coupled to a 54 kW generator. The t-001's rear wheels are driven by the motor, which is directly coupled to the differential; the engine acts only as a 'range-extender' to run the generator. This gives an all-electric range of up to 106 km before the engine kicks in, and fuel consumption over a 200 km route of 2.0 lit/100 km; in simulations, a carbon dioxide output of 22 g/km was achieved.

The van's total possible range between refuelling or recharging stops is over 645 km, and its battery can be recharged in 3-4 hours from a three-phase power supply; different recharging solutions could be adopted in a production vehicle, but this current arrangement would be adequate for a fleet van returning to a fixed base. Performance remains acceptable for a vehicle of this type – a top speed of 130 km/h, acceleration to

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> **Chris Hiett,** IE LEV programme director

100 km/h in 8.5 seconds – and crucially, it maintains a kerb weight of just 1650 kg and a payload of 1400 kg, thanks to its lightweight structural components and body panels.

"This was designed to be all about low carbon, reduced total cost of ownership and fleet volume adoption, a real-world application", says Nick Tebbutt, project director at Ricardo. "The powertrain was picked to support these requirements. IE came to Ricardo saying they wanted to do an RE-EV; they had already carefully calculated the business model for the application and were looking for a practical execution of the idea. The inclusion of the APU gets around range anxiety and is a way of addressing the variability of fleet use, not necessarily doing a fixed route like a bus.

"We used relatively mature technology parts, broadly speaking those available within the timescale of the project – 18 months to build a fully-functioning vehicle from scratch. It's not an experimental powertrain," adds Tebbutt.

However, many of the components were sufficiently new that there was little data from their suppliers. "We had to use our own expert assumptions from previous projects to build a model which best represented the components," says Scott Porteous, a graduate engineer on Ricardo's Development and Simulation team. "Then it evolved as more data became available.

"We did a lot of work looking at the electric motor, looking at the battery, the electric currents you could expect. There were concerns over how hot the battery could get, so we looked in-depth at the current and voltages. The idea was to get as much information from the simulation as possible before the vehicle was built for testing.

"The main focus was the fuel economy we would get out of the engine. As a range-extender, you have the freedom to operate the engine independently of vehicle speed or driver demand to optimize efficiency, but we also looked at its emissions. IE wanted to use as little after-treatment as possible to keep the costs down, but you have a trade-off with efficiency. So we looked at the drive cycles and optimized it to get the best operating strategy which would also meet the emissions requirements, keeping things as simple as possible."

Author Farah Alkhalisi drives the t-001 demonstrator on a test track. Low unladen weight of 1650 kg guarantees a good payload and strong performance; later versions will include lower-power eco mode to allow driver to increase range

Careful control

Developing the vehicle's control systems was key to the optimization. "Ricardo supplied the vehicle controller, which manages components on the vehicle – talking to the battery, the motor controllers, the engine management system and all the base vehicle systems," says the chief engineer on the programme, Andrew Preece.

"Thermal systems, custom control, electrical architectures, vehicle networks, a CAN interface bespoke for this application – our core expertise is in building this sort of solution," adds Nick Tebbutt, who explains that this can then all be taken a stage further by integrating the ideas from Ricardo's Sentience technology (originally reported in RQ Q2/2009 – see box-out). Sentience combines telematics and telecommunication, navigation and intelligent mapping, for forward planning of the route.

"You can schedule the powertrain, for example, if it knows that there is a zero-emissions zone coming up," says Tebbutt. "The system looks at the journey profile and rearranges the strategy to deploy the engine earlier to ensure it has sufficient charge to go through the EV zone. When in range-extended operation mode, it will also use knowledge of the remaining journey distance to ensure that the engine ⇢

Driving the demonstrator

Engineers from Ricardo have been carrying out the final validation and calibration work on the demonstrators at a test track facility, and this phase of the programme is now effectively over. Though some elements of the t-001 prototype may yet be changed for production, and its cabin, its interior TFT-screen displays and driver interface will all be further developed, its powertrain is functioning smoothly. A simple drive/neutral/reverse selector takes the place of a conventional gearbox, and the motor pulls away strongly from a standstill. Fine-tuning of the suspension and power-assisted steering is still on-going, but this is a very complete concept ready to move into its next phase of development.

"The transmission is single-speed, with the motor directly mounted onto the differential," says Andrew Preece. "In addition to providing tractive force, the motor provides the t-001 demonstrator with regenerative braking." During the next phase the braking will be optimized; implementation of an 'eco' mode that allows the user to trade off vehicle performance with economy would also be possible.

Sentience – conscious control

Ricardo's Sentience research vehicle, the result of a 15-month project during 2008 and 2009, was based on a Ford Escape full-hybrid SUV, and explored the application of intelligent mapping, navigation and telecommunications to achieve a reduction in fuel consumption of up to 24 percent. Using topographical data about the road ahead and real-time information on traffic conditions, the technology analysed the best points in the route to engage electrical power, to modulate the engine load to best effect on different gradients and in different conditions, to control acceleration and deceleration to smooth out progress, to maximize the energy recuperation from the regenerative braking system, and to control the air conditioning.

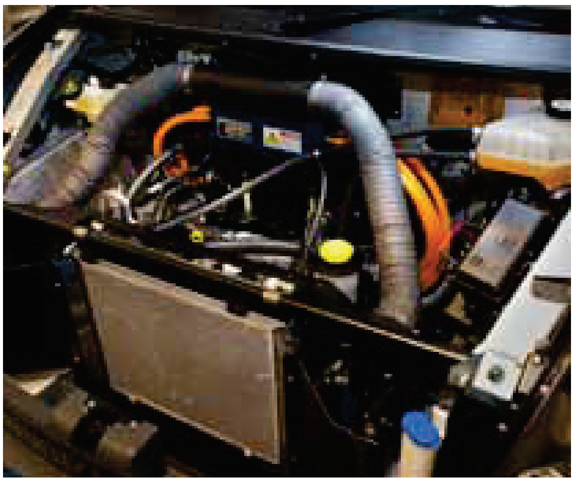
Sentience (defined as "consciousness") was integrated in the research vehicle with its existing cruise control system, and showed the potential for further implementation in conjunction with vision-based control systems such as autonomous braking or crash-sensing technologies, identification of road signs and pedestrian sensing, as well as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2X) devices. Yet despite Sentience's extensive capabilities, Ricardo calculated at the time that, in a vehicle already equipped with a phone and satellite navigation, the technology could be incorporated for as little as 20 euros per vehicle.

The integration of Sentience into the t-001 project was intended from the start, says Intelligent Energy's Chris Hiett. "Our desire was to use a clever way of controlling and optimizing the vehicle. We see it as an area where you can put a lot of options into the system, there's a whole raft of opportunities including how you manage charging and optimizing the route – all benefits for the fleet manager."

Emerald Automotive t-001

Motor	75 kW (nominal); 167 kW (peak); torque 600 Nm (launch)
Generator	50kW (nominal)
Range-extender engine	1.4 litre I4 diesel
Battery	25 kW total, lithium-ion
EV range	106 km*
Total range	747 km*
Top speed	130 km/h (limited)
Acceleration 0-100 km/h	8.5 seconds
Fuel consumption	2.0 lit/100 km over first 200 km*
Carbon dioxide emissions	56 g/km over first 200 km*; 22g/km average**
Kerb weight	1650 kg
Payload	1400 kg
Gross vehicle weight	2950 kg
Rear cargo space	5.2 cubic metres; will accommodate 3 Euro standard pallets

*figures based on NEDC cycle in Ricardo's simulation; **calculated using the official UNECE 101 methodology. This is effectively a weighted average of the vehicle's CO_2 emissions in both battery-depleting (pure EV) and battery-sustaining (hybrid) modes and takes no account of grid electricity CO_2 emissions



provides just enough charge to the battery to return to base – this way the minimum amount of fuel is used and the battery can be fully re-charged using the cheap and potentially more carbon-efficient electricity supply."

The demonstrator vehicles are not equipped with a fully-automated version of the Sentience technology, however, having a basic but bespoke GPS-based mapping tool which logs the route; in this version, pre-logged routes can be programmed and selected via a touch-screen interface in the cabin. "This is a prototype mapping solution for the demonstrator vehicle," Tebbutt notes. "This project is about getting data into the powertrain control system. Long term, we can then talk to the end user to see what interface can be added, what customers want. We can talk to fleet operators about integrating with their existing system, telematics options, and how to download data."

Ultimately, once security issues are resolved, operation via terminals, remote programming or operation via smartphone apps are all possible, along with features such as automated speed or motor output limiting and even driver curfews. But, says Tebbutt, this is not necessarily a priority at this stage of the project. "Our main activities are simulation and control, and how the van will meet performance criteria. What may they want to change in the future? What are the necessary changes for production, and how will these affect performance? The impact of changes accounts for a lot of our simulation work."

Light, but affordable

"This is a different proposition to a converted vehicle with a steel body, and batteries adding yet more weight," says Chris Hiett. "We're managing to maintain a good payload by starting with our own ground-up design." A riveted and bonded aluminium spaceframe structure, with composite exterior panels and lightweight seats and interior components, means that the t-001 prototype weighs in at 1650 kg and its payload is 1400 kg – comparable to that of the similarly-sized short-wheelbase Ford Transit, with which it shares its braking and suspension systems, along with its stock wheels and tyres.

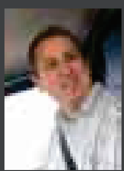
The use of carry-over parts is integral to keeping the overall cost of the vehicle down, though for final production other sources and suppliers could be used, depending on the global location and local market requirements. Design of the exterior has been done in-house at Intelligent Energy by chief stylist Jonathan Gould, using off-the-shelf details such as headlights where possible to further keep cost down, and including the use of easy-to-replace front and rear bumper corners and lower body mouldings.

Affordability has thus been an important aspect to the project, and whilst the range-extended powertrain and bespoke structure will add to the van's purchase price, the selling proposition is the total cost of ownership, says Hiett. "The total cost to a fleet user is reduced, when you take into account the whole life of the vehicle. It is more expensive to buy initially, but over a typical four-year

cycle there are net savings, especially with fuel costs in the UK and Europe." Exemption from levies such as the London congestion charge, and incentives such as CO_2-based taxation, all speed up the payback period.

Large fleet operators including the UK Royal Mail Group and DHL have contributed to the project, providing data on duty cycles and talking to Intelligent Energy about their needs. The aim is to build the van in batches of 10,000, manufacturing at different locations around a central hub: to this end, Intelligent Energy has formed a subsidiary division, Emerald Automotive, to further develop and market the vehicle for production. In the next 24-month phase of the programme, more prototypes will be built, and a small number will go out to fleets – initially in the UK and Europe – for field testing.

Emerald Automotive intends for the van to meet a five-star standard in the Euro NCAP crash tests, and for it to meet emissions legislation in both Europe and in North America. Further into the future, different powertrains are possible on the same flexible and scalable platform: an RE-EV with a gasoline engine for selected markets, as well as fuel cell, an intention from the start of the programme.



"In addition to providing tractive force, the motor provides the t-001 demonstrator with regenerative braking system. During the next phase of developement the braking will be optimized" Andrew Preece, Ricardo chief programme engineer

The use of carry-over suspension, steering and brakes from the Ford Transit helps keep the van's cost down, as does 1.4 litre Ford diesel auxiliary engine (far left). Intelligent Energy plans to build the t-001 in batches of 10,000, manufacturing at different locations around a central hub