Optimized Hybrids

Researchers from the University of Valenciennes and Hainaut-Cambrésis are developing new energy management algorithms to improve the fuel economy of micro and mild hybrid vehicles. dSPACE MicroAutoBox and further modular dSPACE systems are used to implement the control strategies both on test benches and in vehicles.

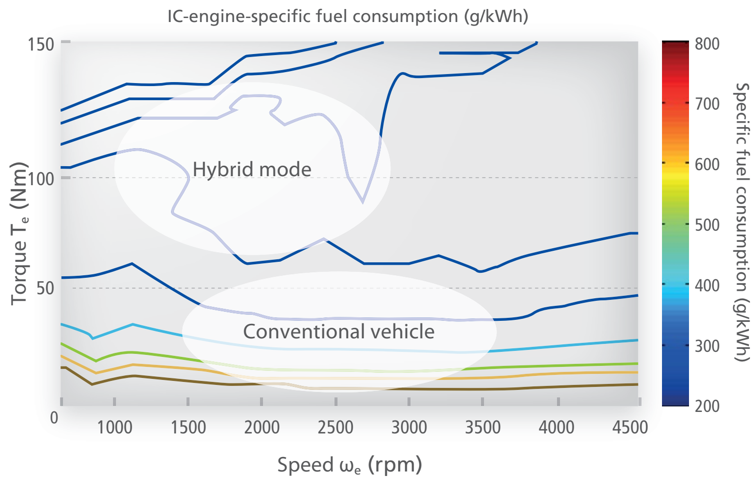
How optimized algorithms in an ECU save fuel

Today, hybrids are on the road, from affordable micro hybrids providing mostly the stop&start feature, up to more expensive systems with significant pure electric mode range. One of the challenges is to improve the control algorithms to reach better fuel economy and reduce emissions. Developing efficient energy management algorithms (EMAs) does slightly increase the hybrid system costs, but it can also improve the vehicle's fuel economy by several percent. That has been precisely one of the research topics of the Laboratory of Industrial and Human Automation Control, Mechanical Engineering and Computer Science (LAMIH UMR CNRS 8201) since 1996.

Energy Management Algorithms

The first functionality to be controlled by the EMA is the engine stop&start. As soon as the vehicle is going to stop, the internal combustion (IC) engine is stopped. When the driver steps on the pedal or selects a gear, the IC engine starts up again. This is one of the major fuel economy sources during urban driving conditions. The EMAs also compute the amount of regenera-

New hybrid test bench to develop energy management algorithms in the lab.



The fuel consumption map provides the specific fuel consumption for all speed-torque combinations of an internal combustion (IC) engine. The optimal engine operating point shifts in hybrid drive mode .

tive braking according to the energy storage level. The basic idea is to recover as much energy as possible (recuperation) without compromising the driving comfort. The driver should not perceive the additional deceleration induced by the electric machine.

The Challenge: Hybrid Driving

The most difficult mode to be controlled is hybrid driving. In this phase, the electric machine and the engine are used together to improve the overall powertrain efficiency. Basically the IC engine load is increased and the resulting additional mechanical power is used by the electric machine to recharge the energy storage while driving. This is done until the energy storage is full. Then either the IC engine load is decreased, but this also decreases the efficiency, or, if available, the pure electric mode can be used. In any case, mathematical optimization is required to ensure good powertrain efficiency.

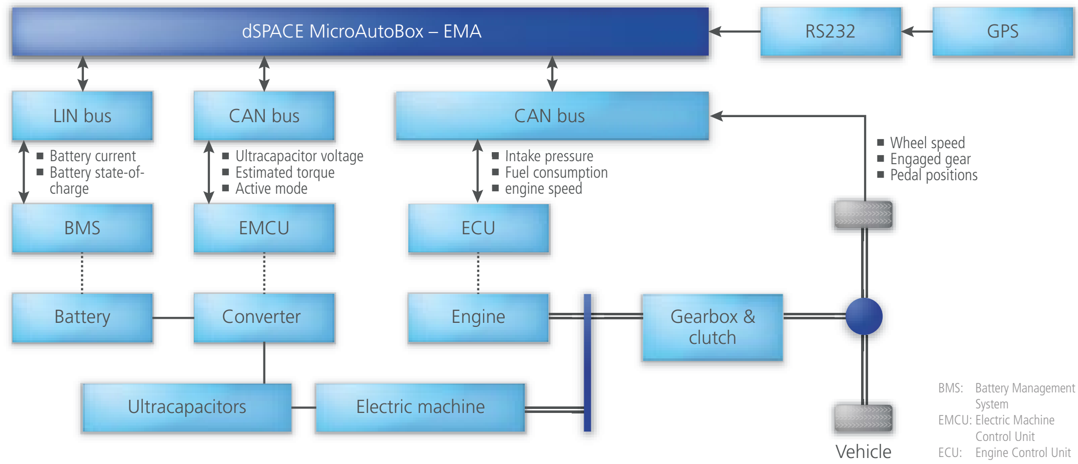
Evaluating Mild Hybrid Vehicles

Hybridization systems with low rated power and small-capacity energy storage systems are less expensive and thus more competitive on the market. These systems provide mostly the stop&start feature along with regenerative braking. Pure electric mode can also be used in some particular situations (low speed, low power request). The BELHYSYMA (Belt Hybrid System Management) project objective was to evaluate the potential of a mild hybrid system. To demonstrate the importance of the EMA, several control laws were assessed.

MicroAutoBox as a Top-Level Processing Unit

Integrating a mild hybrid system into an existing vehicle is a great challenge and requires a wide range of I/O interfaces (LIN, CAN, RS232, and analog I/O). dSPACE MicroAutoBox was chosen as the central processing unit since it provides connectivity for most of the sensor interfaces (analog voltage, LIN, CAN, RS232, etc.) and, if needed, RapidPro units can be used to connect the MicroAutoBox to additional sensors and/or actuators.
Using dSPACE software tools, the GPS data of the NMEA-0183 protocol (a standard for communication between navigation devices) can be easily decoded and integrated into our applications. The RTI CAN toolbox allows importing CAN DBC files (database CAN, a file format for exchanging CAN base data) with just one click, for fast and accurate connection of the MicroAutoBox to the other vehicle control units (engine, electric machine, etc.). The battery is monitored by a specific sensor connected through the LIN port.
Thanks to all the different sensors (analog voltage, LIN, CAN, RS232, etc.) and a set of test bench experiments, a detailed model of the IC engine and the whole vehicle has been developed and calibrated. During urban driving conditions (ARTEMIS driving cycle), the hybrid system and a classical EMA approach allow improving fuel economy by 9.5% (compared with a conventional car). This result is strongly dependent on

> "We have chosen the dSPACE MicroAutoBox and its associated RapidPro extension in order to get a wide range of connectivity. Whatever our future needs, we know that we will have the proper interface with our control system."
>
> *Sébastien Delprat, University of Valenciennes and Hainaut-Cambrésis*



Setup of a prototype mild hybrid system. The energy management algorithms are implemented on the MicroAutoBox.

the stop&start strategy, which is mostly tuned according to the expected driving comfort and number of stop&start operations. By using the proposed EMA, fuel economy is raised to 14.1%. So, by optimization resulting in a simple modification of the control software, fuel economy is improved by another 4.6%.

Next Steps Toward Better Energy Performance

Improving micro hybrid vehicle performance through control strategy design is a real challenge due to the limited capacity of the hybrid system. Nevertheless some interesting results have been demonstrated on the prototype. To improve the experimental analysis, a hybrid test bench was designed, so the EMA can be tested without vehicle or human interaction for more reproducible tests. It is composed of an IC engine and a mild hybrid system coupled to an eddy brake and a motor to emulate the regenerative braking phases. It is controlled by a dSPACE system mounted in PX20 Expansion Boxes. ■

Sébastien Delprat,
Clément Fontaine,
Sébastien Paganelli,
University of Valenciennes and Hainaut-Cambrésis

Acknowledgement
The BELHYSYMA project is funded by the French Nord Pas de Calais region, the European Funds FEDER and the French DGCIS.

Sébastien Delprat
Sébastien Delprat is Professor at the University of Valenciennes and Hainaut-Cambrésis, France.

Sébastien Paganelli
Sébastien Paganelli is Project Engineer at the University of Valenciennes and Hainaut-Cambrésis, France.