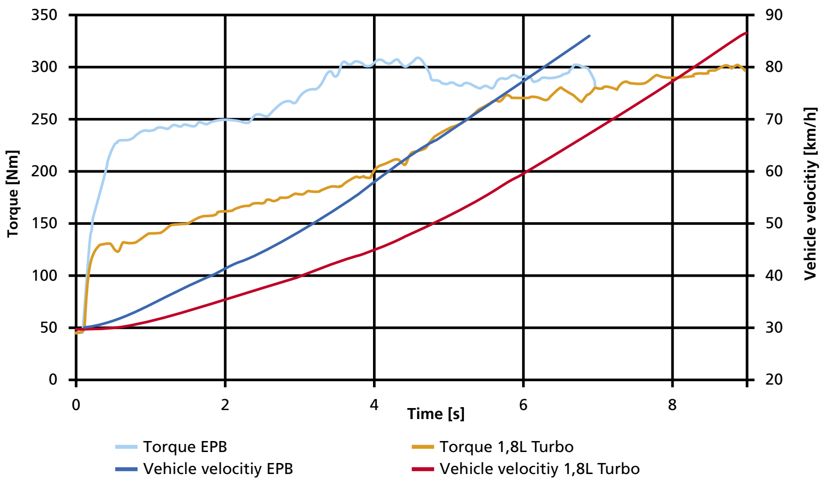
More Torque, Less Fuel

- FEV Motorentechnik: Operating strategy for hybrid drive
- Electric boost
- Verified by dSPACE Simulator

A combination of a turbocharged engine and an electric motor delivers the same power as a larger naturally aspirated engine, but consumes less fuel and cuts toxic emissions. A project running at FEV Motorentechnik aims to optimize the operating strategy for these "downsized engines". They consume considerably less fuel, yet have excellent acceleration behavior. FEV is using a hardware-in-the-loop (HIL) simulator from dSPACE to validate the engine control.

At low engine speeds, turbocharged engines have lower torque than naturally aspirated engines of equal power. Combining the turbocharged engine with an electric motor considerably improves dynamic torque behavior. The electric motor delivers high torque at low engine speeds, so it can ideally compensate for the turbocharged engine's torque shortfall. However, the addition of an electric motor must not be allowed to affect the vehicle's total weight or the overall space requirement of the engine. The electric motor is therefore combined with a turbocharged engine that has a smaller engine displacement, to form what is called a downsized engine. At FEV Motorentechnik, we developed various operating strategies for controlling downsized engines and validated them with an HIL simulator from dSPACE. Our goal is to optimize both motor and engine control to harness the fuel-saving potential, while at the same time improving road performance.



▲ *Full-load acceleration from 30 km/h to 80 km/h in third gear. Electric Power Boost (EPB) compared with a 1.8-liter turbocharged engine.*

Downsizing

Downsizing involved replacing the original engine, a 3.0-liter naturally aspirated engine, by a 1.8-liter turbocharged engine, to which we added an electric motor. The Electric Power Boost (EPB) vehicle from FEV Motorentechnik delivers the power of the original vehicle, which has a larger engine, but emits a smaller volume of pollutants and consumes less fuel. The electric power is used for boosting torque during start-up and acceleration. Because additional energy for the electric motor is required only in short bursts, the power supplied by double-layer condensers (super caps) is sufficient. In conventional vehicles, the way the engine operates is largely decided by the driver. In contrast, hybrid powertrains make great use of the stored algorithms. It is particularly important for the vehicle to have optimum road behavior.

> *"The hardware-in-the-loop set-up enables us to save both time and costs in optimizing the algorithms."*
> ***Marco Jentges, FEV Motorentechnik GmbH, Aachen***

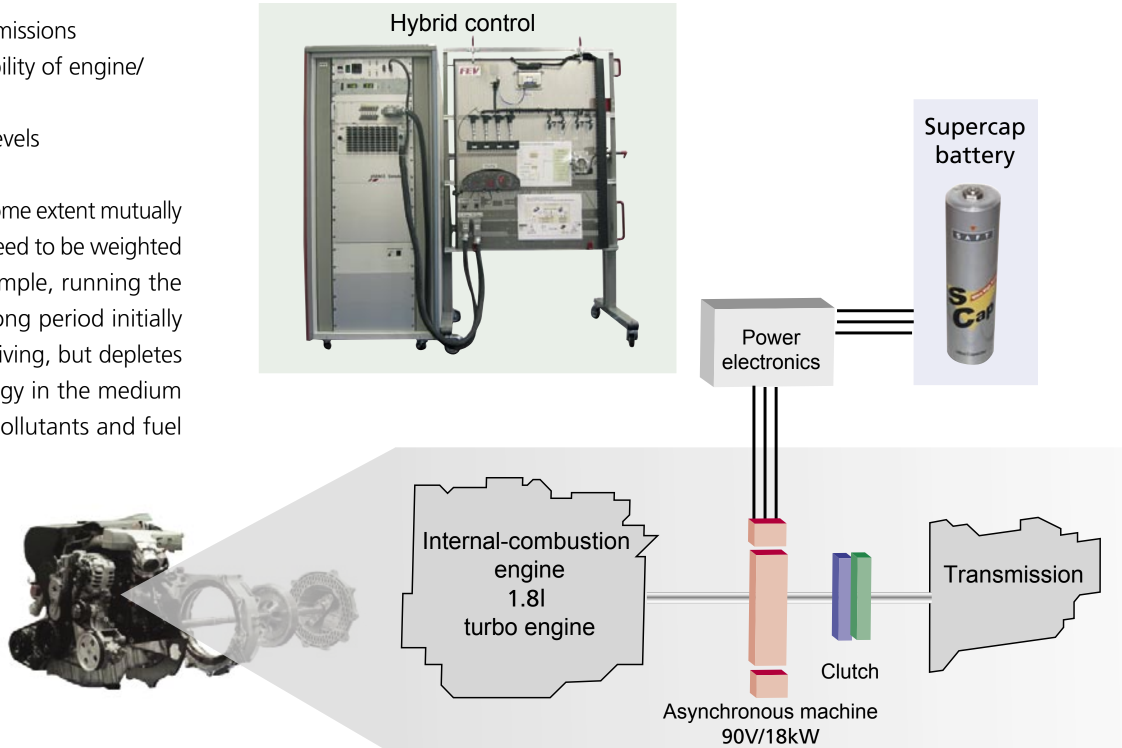
Operating Strategy

The hybrid control distributes the driver's desired torque to the drive aggregates. The control can be optimized according to major concerns such as energy consumption and acceleration behavior. Concerns such as these are expressed in the following objectives:

- To ensure drivability
- To minimize fuel consumption

- To minimize toxic emissions
- To ensure the durability of engine/ motor components
- To minimize noise levels

These objectives are to some extent mutually exclusive, so that they need to be weighted and evaluated. For example, running the electric motor over a long period initially allows pollutant-free driving, but depletes the stored electric energy in the medium term. Thus, reducing pollutants and fuel consumption cannot be the sole focus of the control strategy.



▲ *Topology of the hybrid powertrain.*

HIL Simulation

Even though not all powertrain components were available, at FEV Motorentechnik we were able to study the effect of the operating strategy on the powertrain behavior at an early stage. The HIL simulator from dSPACE was used for this. The real components in the set-up were the engine control of the original vehicle and the hybrid control. In addition to these, some of the original engine's actuators and the cockpit module were connected to one another on a breadboard, via the engine cable harness. The core components in the dSPACE Simulator are the DS1005 PPC Board for computing real-time simulation and the DS2211 HIL I/O Board for simulating and measuring all engine signals. Where powertrain components were not available, they were modeled with MATLAB®/Simulink® and downloaded to the DS1005 via Real-Time Workshop. The models were for the combustion engine, the electric motor, the super cap unit, the clutch, the transmission, the entire longitudinal dynamics of the powertrain, and the driver. Two major criteria, reduced consumption and driving behavior, were studied in several simulation runs.

Results

The measurement results are impressive proof of the difference the EPB vehicle can make, compared with a vehicle with no electric motor. To accelerate from 30 km/h to 80 km/h, the vehicle with the 1.8-liter turbocharged engine needs 8.4 seconds, and the EPB vehicle 6.4 seconds. The basic vehicle with a 3.0-liter naturally aspirated engine requires around 7 seconds. As regards fuel consumption, the EPB vehicle reduced this by around 24% in the New European Drive Cycle (NEDC), as compared with the 3.0-liter naturally aspirated engine. The great benefits of combining hybrid technology with downsizing are therefore considerably reduced consumption under all relevant driving conditions and excellent acceleration values. Using the dSPACE Simulator at FEV Motorentechnik meant that we could begin running comparison tests at an early stage of development, even though not all components were available.

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Glossary

Breadboard – System that provides a simple way of building an electronic circuit without etching or soldering

Super-Caps – Double-layer condensers with high short-term power density

New European Drive Cycle (NEDC) – Legislated drive cycle used to determine levels of toxic emissions and consumption