With MTU’s Hybrid Powerpack, up to 25 percent less fuel consumption and emission-free travel are possible. That is why Deutsche Bahn and MTU are currently testing a Series 642 commuter railcar driven by the prototype of a Hybrid Powerpack developed by MTU. The purpose of the test is to demonstrate that this technology is suitable for day-to-day operations and has ecological and economic advantages over state-of-the-art solutions.

Aschaffenburg/Miltenberg: Hybrid drive systems provide an opportunity to considerably reduce fuel consumption. This is a technology that can particularly benefit applications in which a large percentage of the power is consumed by auxiliary drive units. That applies to construction and agricultural machinery, but is also the case for trains, especially those used in local transport. “Local trains reach relatively high top speeds and run on lines with short intervals between stops. These are the kind of vehicles in which hybrid drives can really demonstrate their strengths,” explained MTU project leader Ingo Lehmann.

To establish to what extent hybrid technology is suitable for day-to-day rail operations, Deutsche Bahn subsidiary DB RegioNetz Verkehrs GmbH Westfrankenbahn and MTU teamed up to work on a hybrid drive solution for local passenger transport, thereby breaking new technological ground in Europe.

**Function and components**
The Hybrid Powerpack is an underfloor drive developed by MTU and put through its paces at their test facility in Friedrichshafen. The Powerpack is based on a 6H Series 1800 R75 diesel engine delivering 315 kW at 1,800 rpm, with an electric motor for maximum 400 kW output. For compliance with the EU IIIB emissions standard in place since 2012, MTU also fitted the Powerpack with an SCR exhaust aftertreatment system with urea tank. The essential advantage of the Powerpack is that all individual drive components are integrated on a common base.

**Who:** DB RegioNetz Verkehrs GmbH Westfrankenbahn  
**What:** Hybrid Powerpack  
**Why:** To promote energy-efficient and ecologically sustainable transport services in the railway sector using the technological expertise of MTU and operative know how of Deutsche Bahn AG.  
**Where:** Aschaffenburg-Miltenberg railway line, Germany

Claus Werner, Project Leader at Deutsche Bahn

“This project is a significant milestone on the way to nationwide deployment of low-emission, eco-friendly trains on non-electrified tracks.”
frame to form a single compact unit. There is no need to install the components one-by-one into the vehicle and then combine them to make up the drive unit. Furthermore, with a Powerpack configuration, linking the different components to the overall system only involves a small number of interfaces.

Thanks to its parallel hybrid architecture, this drive system can be operated using just the diesel engine, just the electric motor, or a combination of both. A starter-generator specially developed for MTU and mounted on the crankshaft can be used either as a generator or electric motor. A frequency converter regulates the flow of energy from the battery to the drive and vice-versa, allowing the operating mode to be adapted to the route profile at any one time. During braking, part of the kinetic energy is transformed into electric power and temporarily stored in a Li-ion battery module. Compared to hydrostatic systems for recovering energy, Li-ion cells boast significantly higher energy density and high cycle stability. During move-off and acceleration, the electrical power stored in the batteries is delivered via a DC/AC converter to the generator which then acts as an electric motor to power the rail vehicle. So whenever it is needed — in tunnels, when entering stations, or passing through densely populated areas — the power stored in the battery can be harnessed.

Hybrid technology is an especially cost-effective technology to use on local lines where braking and accelerating in stop-and-go mode is frequent. This is because its power reserves are not only available for move-off and acceleration, but can also be used for the electrical supply to auxiliary consumers such as air-conditioning compressors. These have been mechanical to date, but their electrification has enabled railcars to roll with even greater energy-efficiency along the tracks. On balance, hybrid technology can reduce fuel consumption and carbon dioxide emissions by up to 25 percent, facilitating low-noise, low-emission rail operations in sensitive areas.

Joining forces on the hybrid drive of the future

MTU’s technical expertise and Deutsche Bahn’s operative know how were pooled on the pilot project. While MTU designed the Hybrid Powerpack, tested it with lithium-ion batteries on its test stand and delivered the prototype, Deutsche Bahn integrated the components and systems into one of its existing VT 642 railcars, conducted the trials, and ensured that the vehicle was approved for regional passenger services.

The project was supported by the Federal Ministry of Transport, Building and Urban Development as part of its ‘Electric Mobility in Pilot Regions’ program, which in turn is coordinated by NOW GmbH (National Organization for Hydrogen and Fuel Cell Technology). At the Innotrans railway exhibition in September 2010, transport minister Peter Ramsauer handed the official confirmation of the subsidy, which amounted to 1.9 million euros, to the project partners. Also
To obtain an optimal overall performance from the power train with respect to fuel consumption and emissions, individual components must interact perfectly. Suitable operating strategies on local transport railcars enable fuel consumption to be substantially reduced. The aim with a hybrid drive is therefore to utilize the combustion engine in such a way that it runs as much as possible at its optimal operating point.

**Strategy 1: Conventional diesel operation**

The required power is provided solely by the diesel engine without the electric motor. The diesel engine operates to full capacity during acceleration, and only with a part of its capacity in normal travel (cruise) mode or when moving slowly within stations. All energy generated by braking escapes unused.

**Strategy 2: Hybrid ‘Eco’ mode**

An alternative to conventional diesel engine operation is combination with an electric motor. With an operating strategy based on performance maps, the diesel engine runs at its optimal operating point, while any extra power that may be needed (e.g. during move-off) is provided by the starter-generator. Part of the power needed for acceleration is provided by the electric motor, meaning that the diesel engine does not have to work to full capacity. Energy produced when the vehicle is braked is recovered and stored. At railway stations or when passing through residential areas, the rail vehicle can run on electric power alone. Deployment of an electric drive with this strategy enables the rail vehicle to use less fuel, emit fewer pollutants into the atmosphere and generate less noise than the diesel engine alone, even at the same output.

**Strategy 3: Hybrid ‘boost’ mode**

If a vehicle is run using a combination of diesel and electric drive, with a starter-generator switched in as a power reserve to cover peak demand, a larger engine can be configured. During acceleration, the diesel engine runs at full load and additional power is provided by the electric motor – enabling the railcar to accelerate more quickly and negotiate steep inclines at greater speed. On average, this strategy enables better utilization of diesel engine capacity, thereby enhancing operative
Possible operating modes of a hybrid drive

1. **Diesel engine in normal operating mode**
   In normal operating mode, the railcar is powered by the diesel engine alone. Diesel engines best demonstrate their strengths during demanding operating phases where they can work at an operating point with a more favorable load profile and across a better performance map to considerably reduce specific fuel consumption.

2. **Combined diesel/electric operation**
   If maximum performance is required, the diesel engine and electric motor work in combination. Extra torque is provided by the electric motor, allowing the railcar to travel uphill or accelerate even faster. That enables travel times to be optimized while substantially cutting fuel consumption and pollutant emissions. The starter-generator is used to start up the engine when it is cold or warm (start-stop mode). Softer starting takes the load off the diesel engine and makes for higher fuel economy. During low-load operation, the engine is run at a more energy-efficient operating point (load-point increase). By means of a generator, any excess energy is used to charge the traction battery and that power can then be harnessed when needed at a later stage.

3. **Electric motor for very low-noise, low-emission operation**
   The electric motor is deployed as the main drive when the rail vehicle is required to run as quietly as possible with minimum emissions — for example when travelling through residential areas or tunnels and during stops at railway stations. The electrical component also makes the hybrid drive more energy-efficient at lower speeds — when the vehicle is moving off or travelling slowly, for example.

4. **Brake energy recovery for battery charging**
   With a hybrid drive, braking power is converted to electrical power which is stored in the traction batteries. This power can be used later, for example, to accelerate the vehicle. That makes hybrid technology particularly cost-effective in local rail transport where there is frequent braking and acceleration (stop-and-go) and hence a large number of charging/discharging cycles.

5. **On-board power supply when train is at a standstill**
   Normally, an alternator is connected to the belt drive of the diesel engine which produces electric power for on-board requirements as it rotates. If the diesel engine is not running, the battery empties very quickly. With a hybrid drive, on-board power requirements are completely covered by the lithium-ion cells, whose energy density is substantially higher than that of comparable hydrostatic recuperation systems. That means that mechanically-driven auxiliary consumers can be electrified independently of the diesel engine and their power supply finely adjusted to cover their actual requirements. Doors, display instruments, the cab console, on-board lighting and other consumers can all be supplied reliably with electrical power without having to switch on the diesel engine — when the train is at a standstill in a station, for example.

Precisely when the crankshaft starter-generator is switched in as an electric motor or as a generator is critical to the energy balance of a hybrid drive system. Optimization is taken care of by the Hybrid Powerpack control unit which can process route and timetable data from an external source or learn route and timetable requirements itself during operation.
Route profile Aschaffenburg - Miltenberg

- Length of route: 37 km
- Number of stopping points: 14
- Red sections: where the train driver can use power previously stored (in green sections) to move off or boost acceleration (i.e. as additional power).

A drive solution fit for the future and daily operation

Once accredited for passenger services, the hybrid railcar will be deployed by Westfranken-bahn on the line between Aschaffenburg and Miltenburg in the region of the lower Maine River in Bavaria. “With 14 stops on a 37-kilometer stretch of single track, this route offers ideal conditions for testing under stop-and-go conditions,” explained Claus Werner. The insights gained from passenger service will flow into subsequent projects. Technical standards are also to be defined for other hybridization concepts.

“Our aim in the coming years will be to test this technology on other vehicle types, and get to the stage of series maturity for its use on commuter railcars,” said Ingo Lehmann, project leader for development and testing of MTU’s Hybrid Powerpack. Hybrid technology will be module-based so that it can be used for other engine series and also other applications, involving, for example, working machinery.

Hybrid drives hold tremendous potential for rail vehicle manufacturers and operators alike. They comply with current EU Stage III B emissions regulations and future emission stages and reduce operating costs at the same time. Furthermore, existing diesel-driven railcars can be re-powered using ecologically sound procedures so that they perform with the same reliability, cost-efficiency and eco-friendliness as brand new vehicles when they are put back on the tracks.

Hybrid technology also allows existing railway infrastructures to be used more effectively. Hybrid vehicles could be run on sections of track where diesel-driven railcars are prohibited – for example in tunnels or in roofed railway stations. Ultimately, passengers benefit as well, not only from the bigger choice of connections, but from the reduced noise levels and fresher air on the platforms and in the trains. “Used in local passenger services, hybrid drives have both medium and long-term economic and ecological advantages over current technology.” summed up Claus Werner. “This project is a significant milestone on the way to nationwide deployment of low-emission, eco-friendly trains on non-electrified tracks.”

MTU Friedrichshafen GmbH
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