Electrified logistics

The volume of goods transport is on the rise all over the world – and there is no end in sight to this upward trend. Will it still be possible to achieve the ambitious climate goals that have been set? Will truck transport even be affordable once we reach the end of the oil era? A current Siemens research project reveals new paths to explore.

A test track, straight as an arrow, deep in the pine forests of Uckenmark, in the German state of Brandenburg. Two trucks quickly approach on the three-lane concrete track; one moves out and overtakes the other. A perfectly normal maneuver – were it not for the conspicuous pantographs on top of the driving cabs and the overhead lines above the track. Is this some kind of train? But where are the rails?

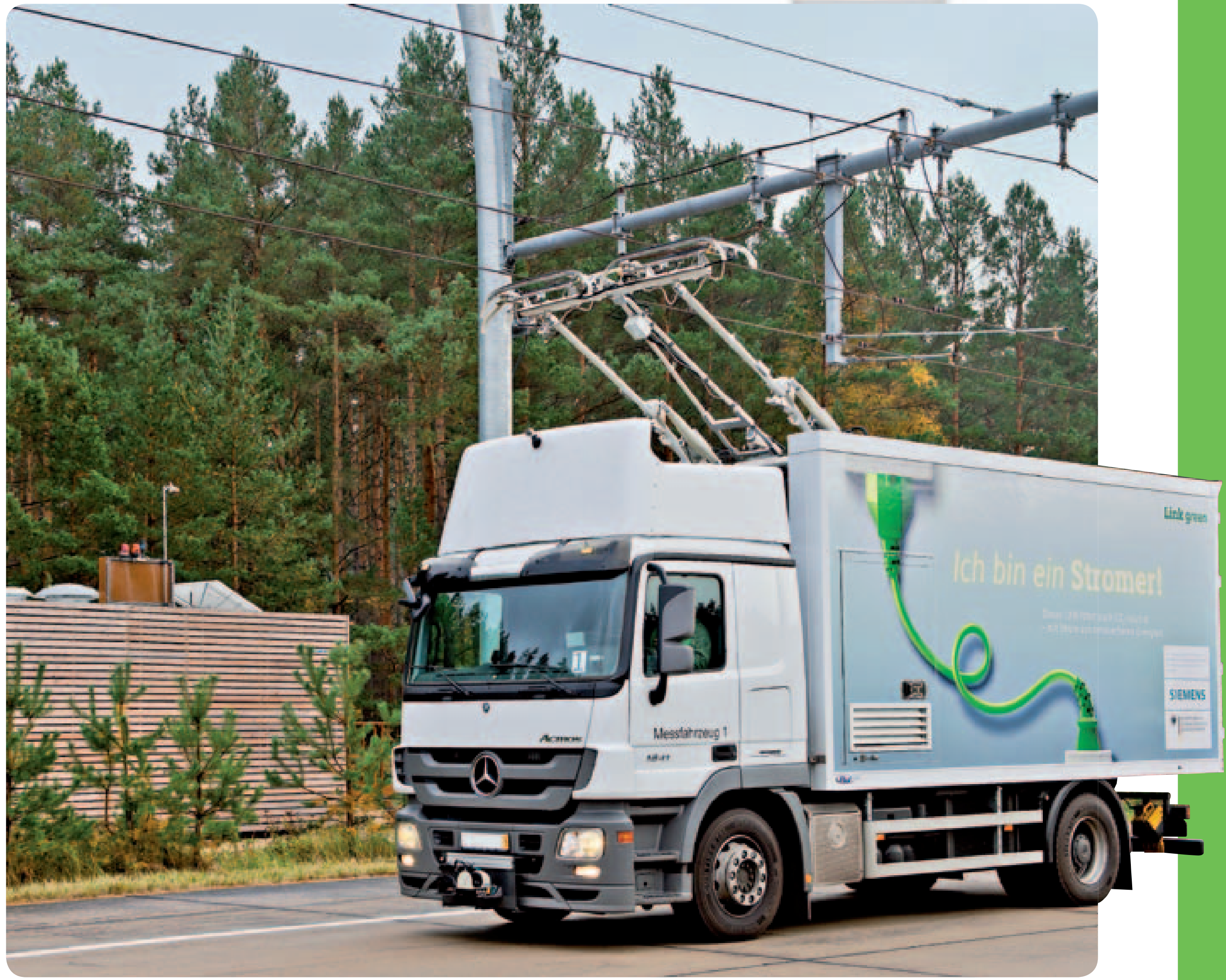
There are none. “The trucks drive like any other truck on the road,” says Holger Sommer, head of the Siemens research project “Electromobility of heavy commercial vehicles for environmental relief in metropolitan areas,” or ENUBA for short. “The only difference is that our vehicles are driving on an electrified highway and can draw current from overhead lines using special pantographs.” In other words, the trucks are driven by electric motors and draw their current directly from contact wires, like trolleybuses or trains. When passing other vehicles or driving on non-electrified roads, however, they are powered by a diesel motor and its connected generator.

The background to this unusual Siemens project is a very real and urgent problem: numerous analysts and forecasters predict a sharp increase in global transport services over the coming decades – of at least 50 percent by 2050, and even twice as high in some regions depending on the scenario. Regardless of which scenario actually unfolds, this means that if transport capacities are not expanded considerably in the coming years, bottlenecks will be unavoidable.

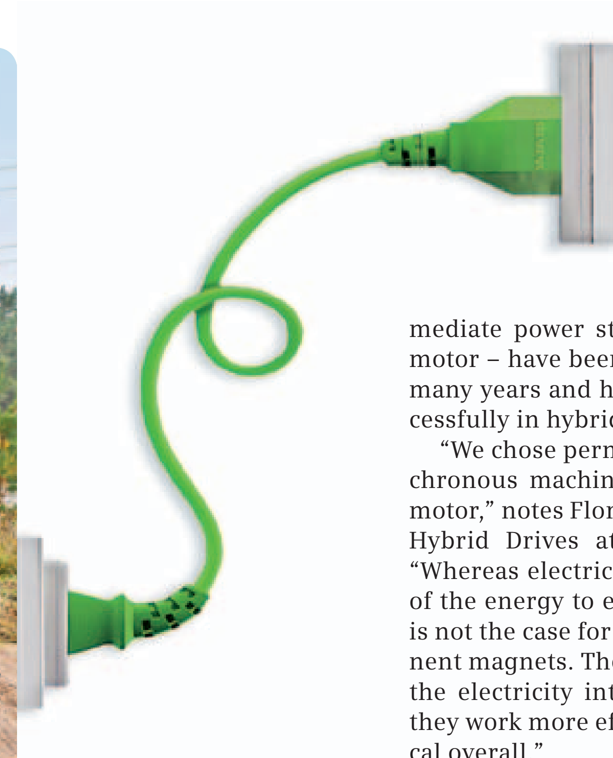
Trucks become eco friendly

Goods transport by rail is rightly considered particularly productive, energy efficient and environmentally friendly. Of course, shifting more goods onto the rail network is no simple matter – not every transport task can be accomplished by rail. Furthermore, in many cases railway companies are scaling back their comprehensive services and concentrating on point-to-point connections between major cities. Many no longer offer parcel and express services at all. Quick and reliable road transport service is therefore required to undertake these tasks. The knock-on effects are well known: much greater consumption of fossil fuel, further increases in emissions, and the certainty of not even coming close to meeting climate goals. So how can truck transport be managed for better energy efficiency and environmental protection?

> “There are a range of good arguments for electrifying truck transport, such as environmental protection and less dependency on oil.



Proven Siemens components take care of electricity supply.



> “Diesel-electric hybrid drives offer several advantages in regard to efficiency.

“There are a number of strong arguments for electrifying truck transport,” says Dr. Michael Lehmann, chief system engineer at Siemens Mobility and Logistics. For instance, while combustion engines only provide the highest performance within certain speed ranges, electric engines provide maximum torque from a standstill, which is perfect for getting a fully loaded truck moving. Electric engines do not require complex mechanical constructions such as a manual transmission. Unlike combustion engines, which only have efficiency of around 40 percent, electric motors convert almost all of the electric energy into kinetic energy – while offering almost completely CO_2-free operation.

“A particularly exciting aspect of electromobility,” says Lehmann, “is that electric energy can be generated in different ways – in the vehicle with a diesel motor and generator or with fuel cells, or at stationary power plants using renewable resources like the sun, wind or biogas.” Not only can this help protect the environment, it can also make transport less and less dependent on dwindling oil supplies and the political situation in exporting countries. “We engineers have been developing electric rail systems for over a century; we know about their advantages at high speeds and their excellent transport capacities. So it makes perfect sense to combine the principle of electric rail transport with the flexibility of the road network.”

As part of its ENUBA research project, assisted by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), in just 15 months. Siemens developed an entire concept for using electric energy in road goods transport. The engineers built evaluation models and prototypes to test the systems – e-trucks, power supplies, roads and control stations – on specially constructed test tracks in Brandenburg.

Since the commercial vehicles market does not currently offer any suitable electric goods vehicles, the engineers from the Siemens Drive Technologies division built series hybrid drives into two standard 18-ton Mercedes-Benz trucks (see box on page 31). To begin with they installed a generator in place of the now superfluous manual transmission. This generator is driven directly by the truck’s diesel engine and can provide the electric motor with power on non-electrified roads via a drive shaft. These diesel-electric drives – essentially composed of a generator, a rectifier, intermediate power storage, a converter and a drive motor – have been used in railway technology for many years and have recently been deployed successfully in hybrid city buses.

“We chose permanent magnet three-phase synchronous machines for the generator and drive motor,” notes Florian Zauner, project manager for Hybrid Drives at Siemens Drive Technologies. “Whereas electrically excited motors require part of the energy to establish the magnetic field, this is not the case for self-excited motors with permanent magnets. They transform up to 97 percent of the electricity into kinetic energy, which means they work more efficiently and are more economical overall.”

Diesel-electric hybrid power offers other efficiency advantages. For instance, the combustion engine, which only drives the generator, is not subject to the frequent load changes of normal operation. It can therefore constantly run within its optimal speed range and consume as little fuel as possible. It also allows for electric braking with the drive motor, which then also functions as a generator and feeds the energy that has been recouped back into the power supply system. “Recuperation is already the technical standard in trams and trains,” says Zauner, who is firmly convinced that this is a drive concept for the future. “The serial hybrid drive system is incredibly flexible, since motors burning diesel, gasoline or liquefied gas can be installed to power the generator, depending on requirements. Even fuel cells, gas turbines and battery stacks could be incorporated into the design – after all, the electric motor doesn’t mind where the electricity comes from.”

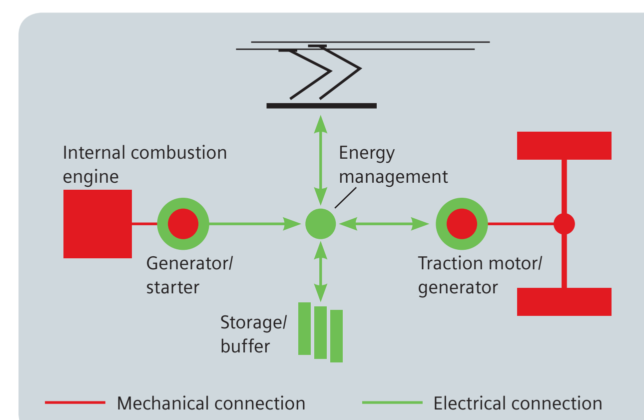
Naturally, to be real dual-system vehicles, the ENUBA trucks – which Daimler and Siemens recently agreed to continue developing in a more intense collaboration – have to draw their power from overhead lines. “When it comes to the traction power supply it makes sense to choose a tailored solution using proven Siemens components installed in an attractive housing,” says systems integrator Dr. Michael Lehmann. Using a transformer and a rectifier, the Siemens engineers converted the three-phase current supplied by the public grid into 650 volt direct current. In addition, a controlled inverter ensures that the electric braking energy from the vehicles is compatible to be fed back into the grid. “This is common practice in trams today, but a technical inno-

The e-truck’s hybrid drive

In general terms, “hybrid drive” describes the combination of different drives to supply power. With a series hybrid drive, like those built into the Siemens e-trucks, a combustion engine and an electric drive motor operate one after the other, that is, in series.

The combination of a diesel engine and a generator works as an on-board power unit to produce the necessary traction current. The e-motor takes sole responsibility for moving the vehicle: it drives the wheels via the axles using a conventional drive shaft as in a regular truck, or it can use wheel-hub motors to drive the wheels directly. There is no mechanical connection between the two motors.

The ENUBA concept with its open infrastructure, however, is open to all electric hybrid drives. This could be, for example, a parallel hybrid drive, a battery storage or a solution using fuel cells.



vation for road vehicles," says Lehmann. "And our overhead lines have certain special features too."

Unlike the overhead lines for a tram, this 1,500-meter-long system uses two parallel contact wires. Whereas rail vehicles can return the current via the track, road vehicles such as trolleybuses always require bipolar systems to supply and return the current. In addition, since trolleybuses drive relatively slowly, they can operate with relatively simple systems. The ENUBA project, on the other hand, demanded a practical solution for general goods transport – which means trucks traveling at 90 km/h on the freeway. "This is why we installed elastic-mounted contact lines with run-on and run-off contact wires, like those used on railways," says Lehmann. "With these catenaries the carrying cable and the contact wire are always kept at a high tension by a tensioning mechanism inside the mast. This is a more expensive solution, but it ensures a technically sound transmission of current to the vehicle – even at high speeds – and reduces wear on the equipment."

Intelligent electricity consumer

The double pantograph on the e-truck was designed from scratch. The pantographs normally used on trolleybuses are only suitable for low speeds and cannot reestablish contact with the wires while moving, as is necessary after a passing maneuver. The pantographs used on trains, on the other hand, are designed for a single overhead line suspended in a zigzag pattern. They are fixed at the sides and only designed to press against the overhead line with a force of around 100 Newton. "By contrast, the pantographs of our e-trucks must be able to reliably disengage and reengage at any speed up to 90 km/h and actively correct movements within the driving lane," explains Frank Gerstenberg, who is responsible for developing the pantographs at the Berlin research center of Siemens Infrastructure Logistics.

Normally the engineers in Berlin use their sophisticated mechatronic systems – featuring actuator, sensor and image processing technology – for automatic sorting and conveyor systems. For this project they took less than a year to develop a novel pantograph that offers the best of both worlds: "The pantograph rests on the frame of a trolley pantograph; it has two rockers and a pneumatic system that are used to control the position and the upward pressure against the contact wire," says Gerstenberg. "And we have equipped it with a highly intelligent control system: it operates largely autonomously, for instance by recognizing the presence of contact

As with trolleybuses, e-trucks also require two contact wires.

> "The control system for the two contact wires automatically compensates for movements within the driving lane.

wires and establishing contact automatically. Because the overhead lines are positioned over the middle of the lane, the control system decides whether the pantograph should compensate for driving movements or shift sideways to minimize wear. It also disengages from the contact wire as soon as the driver changes to the passing lane or suddenly moves to avoid an obstruction." This complex, intelligent control system relieves the driver of all tasks related to the e-truck's electrical operation.

The practical benefits of this innovative electromobility concept were already evident in the first months of testing, reports Holger Sommer, head of the research project: "In around 1,700 test-drive and measurement runs, including many with trailers and a total weight of 40 tons, the concept and the technology faired exceptionally well." The two e-trucks covered a total of 8,500 kilometers, beneath overhead lines and on non-electrified stretches of road. They put the pantograph control technology to the test with emergency stops, test runs with obstacles, evasive and passing maneuvers – to the complete satisfaction of the engineers.

"In parallel with the practical testing, the Siemens experts carried out thorough conceptual studies on the road traffic and control aspects of this new transport system," says Sommer. "These included studies on the design of an energy measurement and accounting system, the integration of the electric vehicles in existing traffic flows, and user registration." Specialists from Siemens Mobility Consulting also answered the following questions: Under what circumstances can CO_2 reduction targets actually be achieved? What economic opportunities and risks does the concept involve? What will be the bottom-line cost of electric operation for the state and for the freight carrier? What would successful operator models look like?

The experts also examined suitable areas of application and the system's potential to add value. They came to the conclusion that the concept could reach the break-even point after just a few ten thousand kilometers traveled per year. For the environment, however, the eHighway would start showing benefits from the first kilometer traveled. □

eHighway and e-truck in practice

- Infrastructure such as access roads, storage and handling facilities, routes and workflow will remain in their usual state for customers, freight carriers and drivers. The type of vehicle driven is the only thing that changes.
- The "road" infrastructure is generally in place already. It can be expanded, upgraded to eHighways and enhanced with established traffic control measures at a relatively low cost.
- As dual-system vehicles, e-trucks are particularly flexible. They can be driven within the electrified network or – using diesel-electric power – on non-electrified roads.
- Given the right energy mix, electric operation can be CO_2 neutral, which translates into a considerable reduction in emissions. The vehicles can recoup braking energy and exchange this energy with one another via the overhead lines or feed it back into the grid. When running on diesel-electric power the combustion engine runs within the optimal speed range, consuming the least possible fuel.
- In future designs the vehicle manufacturers could leave out components such as heavy manual gearboxes or – when a wheel-hub motor is installed – the drive shaft and differential. This would result in weight and volume savings and make completely new designs possible.