Hybrid drive systems for ships and trains

Cross-fertilization

Hy|bri|da: “A thing derived from heterogeneous sources or composed of incongruous elements”

[From Latin hybrida, (h)ibrida]

As yet the rose and the ornamental onion are distinct flowers. But will they ever be made into one? The diesel engine and the electric motor are one step ahead in that regard. They have already been combined into hybrid drive systems. MTU will soon be testing out prototypes in the field.

Up to now the VT 642 railcar has been driven by a conventional MTU PowerPack. Now it is to be fitted with a hybrid system.

It is the queen of flowers, the rose. But would it be possible to add to its attributes by giving that queen a very special crown? For example, by crossing it with an ornamental onion? A plant that is resistant to all hardships? Then we might create a flower that is the star of every show – the onion rose. It would not only outshine every other flower, it would also last much longer. As yet there have been no such cross-fertilization attempts in the botanical world. MTU is one step ahead in that regard. Diesel engines combined with gas turbines have proven themselves as marine propulsion systems over many decades. And diesel engines are now being joined together with electric motors to create new hybrid systems. As yet they are still delicate seedlings. But to find out if they can be grown into hardy plants, prototypes are soon to be tested out in research projects.

Chili chocolate is one. Grapefruit is another. Will the onion rose be the next? Anywhere and everywhere we are surrounded by hybrids. Be it merely a mixture of chili and chocolate or a cross between and orange and shaddock or even between onion and rose. Even things seemingly very different at first sight are combined with one another to produce the proverbial whole greater than the sum of its parts. MTU diesel engines have had a perfect hybrid partner for nearly 40 years – the gas turbine. The two are joined together in propulsion systems for ships in order to utilize the advantages of both systems at the same time. On long-distance trips or at low speeds the substantially more economical diesel engines operate alone, while the gas turbines are kept in reserve for the highest speeds. A highly successful model for large naval vessels in particular. It enables fuel-efficient cruising as well as ultrahigh top speeds.

Diesel engine meets electric motor. But now the diesel engine has found a new hybrid partner – the electric motor. Actually they have known each other for many years. They have worked together for a long time in diesel-electric traction systems, in which electric motors are powered by a diesel-driven generator. And now MTU is researching into uniting electric and diesel units in a hybrid system to get the best of both worlds. A diesel engine on its own is powerful and durable. The electric motor is quiet and produces no emissions. The two together will make new hybrid drive systems possible that not only offer higher performance but also need less fuel and produce lower emissions. The principle is always very similar:

> For normal traction, the diesel engine is used on its own
> Whenever zero emissions or silent operation are required, the electric motor is used on its own
> Both power units are used in combination when maximum performance is needed immediately, such as when pulling away, accelerating or climbing.

An odd couple? As unusual, maybe, as the diesel engine and electric motor might first appear. But they are growing together and creating hybrid systems.

Hybrid star of the rails. Significantly lower fuel consumption and emissions than with conventional diesel-powered trains, virtually silent operation at stations and substantially lower life-cycle costs – hybrid drive systems in trains are a worthwhile investment, especially for local services. Trains used for that type of duty have to frequently brake and accelerate again, and that is precisely the pattern utilized by the MTU rail hybrid system that is to be trialed in a research project to be conducted jointly next year with the DB RegioNetz Verkehrs GmbH Westfranken. Every time the train brakes, the energy is stored in a battery. And whenever it is required to power the electric motor, the battery gives that energy back – when pulling away, in stop-go conditions, when tackling uphill gradients or when accelerating. Then the electric motor assists the diesel engine so that less fuel is required. When the train needs to run as quietly and as cleanly as possible, for example in residential areas or stations, the electric motor operates on its own.

For this project, one of MTU's partners is working to MTU specifications on the development of a very special electrical machine, a crank-shaft starter generator (CSG). It runs directly off the crankshaft of the diesel engine and can function both as an electric motor and a generator. A frequency converter controls the flow of electricity from the battery to the motor and back as required.

Predictive control. A strikingly beautiful feature of the MTU rail hybrid system is its special rail hybrid controller. It controls the use of the two power units with the aid of an electronic service timetable. The timetable contains details of the precise speeds at which the train must travel at various points along the route in order to be on time. The MTU rail hybrid controller decides before the journey even begins when the diesel engine will be used alone, when the electric motor will be brought in and when the train will run on electric power only. During the journey, the controller continually checks whether the train is still on time or is behind or ahead of schedule. If the controller identifies that the train is not keeping to the timetable, it checks whether it would be helpful or possible to change the traction mode – and does so without input from the driver. "That predictive monitoring is unique in the rail sector," reveals Ingo Lehmann, MTU project manager for the hybrid PowerPack. "The system is patented and enables us to minimize the fuel consumption as much as possible as we only ever use the amount of power actually required to keep to the timetable," he adds. The rail hybrid controller also manages the entire traction system peripherals: cooling systems, preheating equipment, auxiliary drive systems, auxiliary peripherals and the exhaust treatment system. That is because the PowerPack contains an SCR system to reduce emissions and keep them within the Stage 3B limits.

The first railcar with a prototype MTU hybrid traction system is due to start service in the middle of next year. In cooperation with a development team from Deutsche Bahn, a Siemens Desiro VT642 Class railcar operated by Westfrankenbahn, a subsidiary of Deutsche Bahn, is being converted as part of a project sponsored by the German Transport, Construction and Urban Development Ministry. Up to now the train has been driven by a conventional MTU PowerPack. Preliminary studies indicate that a 15 to 25-percent fuel saving may be possible depending on route profile. "In this form and with this type of performance, our hybrid system is unique in the rail sector," points out Rainer Breidenbach, Tognum COO with responsibility for the Engines business unit.

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>
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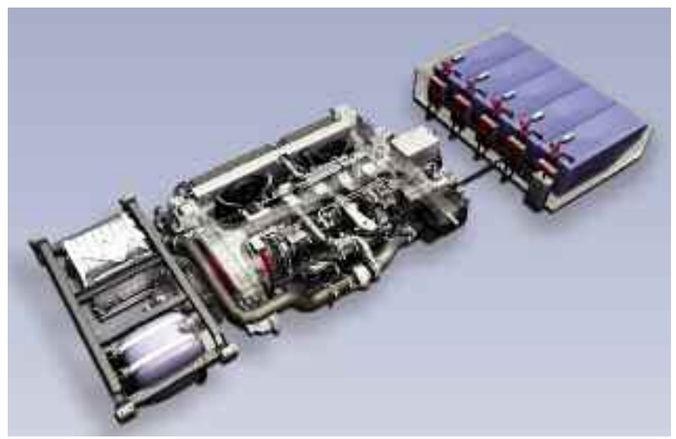
MEMO

The fuel cell forms a hybrid with a gas CHP module.

Hybrid heat and power plant: a milestone in energy supply

Another hybrid: the HotModule already guarantees reliable and, above all, virtually zero-emission electricity generation on its own. But combined with a modular gas heat and power plant its flexibility is substantially increased. The two are linked together by a common heat pipe. While the fuel cell runs at constant output to cover the base-load demand, the gas CHP module is more variably controllable. The hybrid controller constantly adjusts its output to the immediate energy demand and the amount of biogas fuel available.



The hybrid PowerPack for rail traction essentially consists of a diesel engine, a crank-shaft starter generator, a frequency converter and a battery for storing the braking energy.

« Yachts with our hybrid system can maneuver powerfully, sail out of the world's biggest harbors without creating any emissions and the owners can enjoy the silence of secluded coves thanks to their onboard electric power supply. »

Dr. Gerhard Filip, MTU marine hybrid project manager

Luxury yachts made by British builder Sunseeker may be running on MTU hybrid power in the near future.

Hybrid propulsion for ships. Winding one's way out of the harbor using electric power, then deploying the diesel engines to whizz at full speed across the water in time to relish the romantic atmosphere and peacefulness of the bay late in the evening. What sounds so tantalizing could soon become a real scenario for yachts. Together with the British yacht manufacturer Sunseeker, development engineers at MTU are soon to test a hybrid propulsion system as part of a research project. As with hybrid rail traction, the crankshaft starter generator (CSG) is coupled with the diesel engine. However, on the yacht this generator is separated from the diesel engine by a clutch. With the clutch disengaged, the CSG can take the ship from the harbor out into the open sea. At this, the electric motor showcases all its advantages: it is quiet, produces no emissions and reaches its maximum speed immediately. At a maneuvering speed of six knots, batteries can provide the motor with energy for almost one hour. "That's enough time to depart from even the world's largest marinas" explains Dr. Gerhard Filip, applications engineer at MTU. If the captain then decides to go at full throttle, he will deploy the full power of his diesel engines. The coupling will engage and the combustion engines take over the ship's propulsion. During this phase, the CSG, in its role as generator, will recharge the batteries so that they will be available for their next task: to provide power for the electric motor as a short-term back-up for the diesel engines so that the yacht may accelerate even faster. When the boat is anchored in a bay, the captain can revert to the batteries for his on-board power supply and switch off the on-board power generator. This not only means less noise but also prevents the emission of pollutants. Another advantage of the marine hybrid system: in order to save fuel, the yacht captain may shut down one diesel engine when cruising at moderate speed and drive the second propeller using the electric motor (e-shaft mode). "One third of the time, yachts only move with one third of their rated power output. One diesel engine is enough to do the job, saving the fuel for the second engine" adds Dr. Filip.

Final piece of the jigsaw. One of the keys to a successful hybrid drive system and, at the same time, one of its greatest challenges is the battery. Not only does it determine the range of the electric motor, but also the weight, space requirements and cost of the entire drive system. Lithium-ion batteries currently represent the best compromise between size and performance and are thus the ideal energy stores for hybrid systems. They are already widely used in entertainment and communication devices such as laptops and mobile phones, and they are also well established in the automotive industry. But the batteries for rail and marine power have to be considerably more potent and durable. As yet there are no energy stores on the market that can meet those requirements. MTU is therefore taking part in a publicly sponsored research project involving the development of lithium batteries tailored exactly to meet the requirements of vehicles that have to deliver high power levels off-road.

And that will be another factor in ensuring the MTU hybrid seedling continues to grow strongly. So maybe we will look back in 40 years' time and see that the diesel engine has had just as successful a relationship with the electric motor as it has so far with the gas turbine.

Lucie Dammann

To find out more, contact:
Ingo Lehmann
ingo.lehmann@mtu-online.com
Tel. +49 7541 90-3467

Dr. Gerhard Filip
gerhard.filip@mtu-online.com
Tel. +49 7541 90-4007

MEMO

Advantages of the marine hybrid system

Comfort
> Silent and low-vibration running
> Silent onboard power supply

Environment
> Maneuvering in harbors without producing emissions
> No emissions from onboard power supply at night
> Lower emissions when accelerating

Performance
> Significantly faster acceleration
> Smoother transition from electric to diesel power

Economy
> Five percent less fuel consumption due to e-shaft mode (shutdown of one diesel engine); accordingly lower CO_2 emissions
> Longer diesel-engine service life
> Downsizing of diesel engines

Amazing! The onion rose is fully grown and in full flower. But actually only thanks to computer generated imagery. MTU hybrid drive systems, on the other hand, could soon be reality.