Multifunctional track maintenance vehicles for conductor rail and battery operation

Münchner Verkehrsgesellschaft (MVG) is receiving completely redesigned and newly developed hybrid track maintenance vehicles for working in and on the underground railway network.

Fig. 1: With its symmetric design, the electric track maintenance vehicle for Munich's public transport company is designed for bidirectional operation.

Source of all illustrations: Robel Bahnbaumaschinen GmbH

MARTIN RUDHOLZER | ANDREAS SCHIRMER

For several decades, the world's railways have been using track maintenance vehicles (TMVs) frequently for work, transport, and traction – and they are also being used more in urban areas. To date, these vehicles have always been diesel-powered. Now there is a trimodal drive option available. It differs significantly from previous solutions: the new vehicles run and work electrically, have two cranes for unrestricted working in both directions, allow multiple heading, and can be controlled by radio. The new Rorunner Level 3 E³ is the first TMV with alternative drive technology for Munich's underground railway. Handling battery technology of this scale as an energy storage system leads to new questions, risks, and challenges.

New vehicle design

The hybrid vehicles, currently undergoing testing and acceptance procedures, run electrically on the conductor rail. They have powerful batteries and only have a diesel engine on board as a fallback level for longer deployments. Despite their overall design being largely symmetrical for the first time (Fig. 1), they still have some elements of existing TMVs. However, these are not adapted vehicles equipped with electronic and electrical technology. Rather, the vehicles are specially designed for the new drive technology and its requirements, such as cable routing and installation spaces.

Fig. 2: The battery pack is dimensioned for exactly 3.5 hours of battery-powered working.

Fig. 3: Stability test in superelevation with simultaneous, remote-controlled crane operation.

Munich: fleet rejuvenation and standardization by 2025

MVG operates two battery-powered electric locomotives for traction and logistics in the underground railway network. Instead of the follow-up procurement initially considered, the decision was made to tender for electric TMVs: in the foreseeable future, MVG will deploy ten largely identical maintenance vehicles for a wide range of tasks on the Munich underground rail network (see report on page xx). They are completely manufactured in series at Robel's Freilassing factory. Six two-axle track maintenance vehicles and two four-axle flat wagons have already been delivered.

A new generation: moving away from diesel

Within a few years, the fleet of underground railway maintenance vehicles in the MVG network will be largely electric, quiet, and clean. The advantages of emission-free and low-noise operation in tunnel sections and stations as well as in urban environments are obvious for all users. Staff working with the vehicles also benefit significantly. Increased performance and availability are important in view of ever shorter time windows for working on infrastructure. Standardized machine operation makes staff training and deployment easier.

Fire protection for the battery technology

The much-discussed issue of possible battery fires must also be taken into account for maintenance vehicles. Tunnel operation and the crews' work require the highest level of safety. Not every battery technology known today is suitable for these applications. Although LTO batteries cannot be extinguished, fire incidents are extremely unlikely. The titanate used does not react with the oxides of the negative electrode. This storage technology therefore eliminates the dreaded „thermal runaway" of the battery. This even applies to mechanical damage to the cell structure. These batteries are also high-current capable and short-circuit proof. As problems are usually signalled early on by temperature changes in the cells, every battery pack installed is fitted with sensors and fire alarm cables. Evaluation software monitors the cell life, and there is a fire detection system on the diesel power pack. Battery and signalling technology require additional staff training, first at the factory and then at the customer's premises.

Electric bogie vehicles for emission-free operation

The new, four-axle TMVs must be approved in accordance with Germany's regulations for tramway construction and operation ("BOStrab") as well as railway construction and operation for branch lines ("EBOA"). The customer required a hybrid, bimodal drivetrain able to run on battery and diesel-electric power, with a power-supply option via the side conductor rail (750 V DC) and corresponding pantographs. The trimodal drive concept implemented allows several operating modes:

- Running on power from the conductor rail
- Running and working with battery power
- Running and working with generator-powered energy (diesel engine)

Although working via the conductor rail is possible, it is often ruled out for safety reasons. That is why the relevant section of conductor rail is usually de-energized before working on the track. The diesel power pack is now only intended as a fallback level for special operating situations.

Estimating power and dimensioning the battery pack

In battery operation, the question arises as to the appropriate dimensions of the battery pack (Fig. 2) with regard to the installation space to be provided, but especially from a financial point of view, as the battery is the biggest cost driver.

Fig. 4: The aluminium cab offers space for two identical driver‘s workstations plus five people. Large glass panes provide a generous view of areas around the vehicle.

This meant that the average power requirement for a typical shift had to be determined as precisely as possible and the battery capacity assessed.

With regard to the operating conditions, the customer specified a sample route, the challenges of which were initially recorded using simulations. Shifts were monitored and load spectra were determined and evaluated to make the information even more specific. This was supported by accompanying operating data analyses of the TMVs deployed in Cologne. However, other questions arose: what happens if the line is closed for longer than one night? how effective is the energy recovery? what new work tasks are conceivable?

Recuperation, storage technology, and modularity

Recuperation is used to achieve high energy efficiency: energy recovered on lines with downhill gradients and while braking is primarily channelled into the batteries. When they are full, the energy is fed back into the grid via the conductor rail. A braking resistor is only used when there are no consumers on the move. Selecting the option „Travel on the conductor rail“ saves a massive amount of battery capacity. This means that the vehicle always arrives at its destination with fully charged batteries.

When travelling back, the batteries are recharged en route, so that even the depot should be reached often with freshly charged batteries: half an hour of travel with recharging at the conductor rail corresponds to six to seven hours of charging at the depot.

LTO battery cells were chosen for the storage cells. They are more resistant to ageing than conventional lithium-ion cells while allowing more charging cycles and high charging currents. The energy content is sufficient for 3.5 hours of uninterrupted working.

Fig. 5: The pantograph for the side conductor rail is attached diagonally to the bogie and can be retracted without infringing the structure gauge.

Both the battery module and the battery pack can be easily replaced when they reach the end of their economic service life. The battery pack and diesel power pack are modularized. They have identical mechanical and electrical interfaces, and their installation spaces are the same size. In the future, it may be possible to dispense with the diesel engine and simply replace it with additional batteries.

Symmetrical design, also in detail

In contrast to their predecessors, the new TMVs have a symmetrical design, partly to avoid having to rotate them. One of the specifications was crane work at both ends with a long reach in front of the buffer beam. The cranes are electro-hydraulically operated, each with its own hydraulic circuit. Having both cranes work simultaneously in every conceivable position – even to the same side – requires a complex control system in addition to axle spring locking and lateral outriggers (Fig. 3). An intricate software landscape was required to enable two operators to control one crane at a time via radio remote control. Mutual interference between the radio signals must be avoided.

Two loading beds, one cab

Another specification was the loading beds assigned to each crane at platform level with a payload of up to 1.5 tonnes. The design even made two three-tonne loads possible. Like the entire vehicle, the resiliently mounted aluminium cab with large glass panes has a symmetrical design and offers two identical driver's workstations with a generous view of the area in front of the vehicle as well as space for five people (Fig. 4). The entire vehicle is completely accessible without having to leave it, i.e. without stepping onto the track.

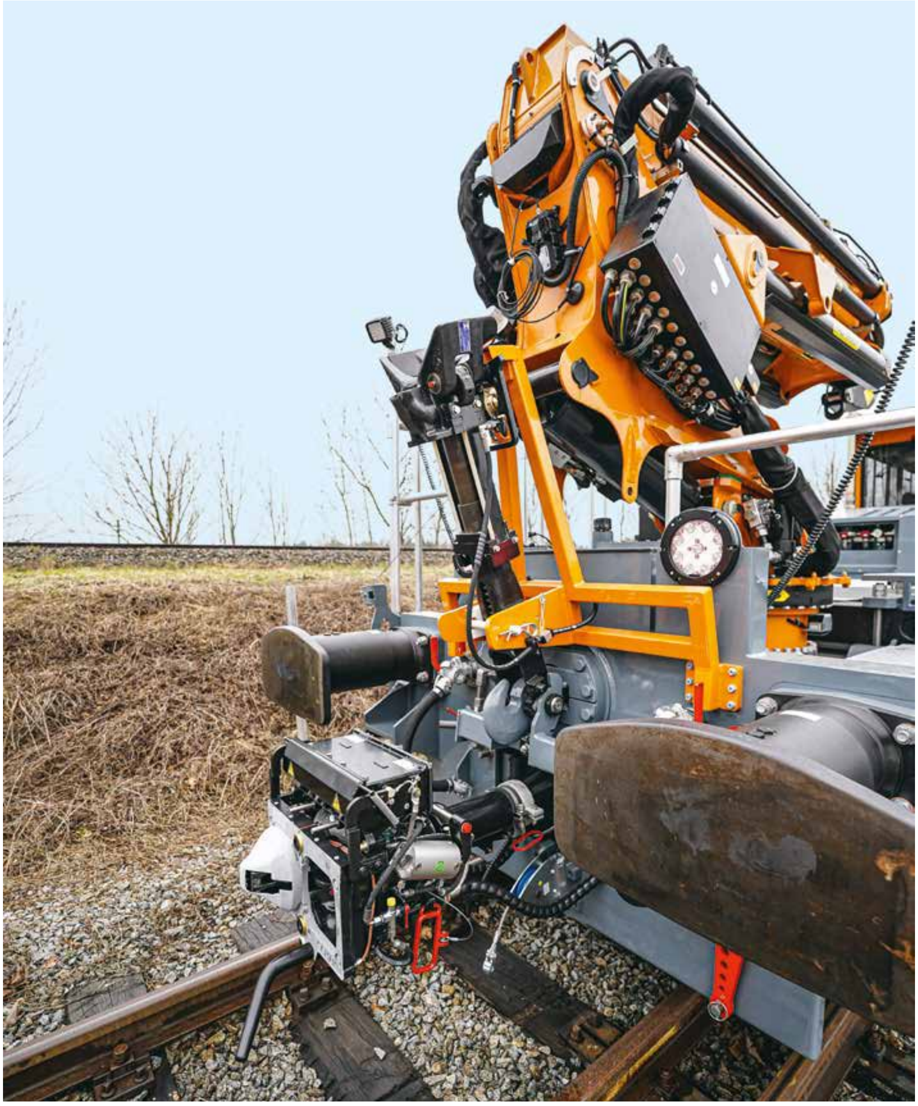

Fig. 6: The vehicles are equipped with a standard draw gear with side buffers, an additional shunting coupler, and a pneumatically lowerable Scharfenberg coupler for operating on underground and heavy rail systems.

Redundant drive units

Both wheelsets of each bogie are motorized and share a motor converter. The presence of two redundant drive units increases operational reliability:
the TMV is still capable of travelling on its own even if one drive group fails. The pantographs are attached diagonally to the bogies and equipped with disconnecting contactors and automatic vehicle earthing (Fig. 5). Unlike conventional pantographs for the side conductor rail, they can be retracted into the bogie using a specially designed device, thereby preventing infringing of the structure gauge. This is necessary to prevent hazards for staff and damage to the pantograph caused by construction materials.

Multifunctional working

The track maintenance vehicles can be used in both directions without restriction. Trailers can be both pushed and towed, or both, at the same time.
Tasks such as transporting long rails require the transport wagons to be located between two TMVs. The train protection system always switches to the vehicle running at the front, and the trailers in the fleet are equipped or retrofitted accordingly.
The vehicle control system recognizes five operating modes:

- Fast transfer travel at v_{max} 40 km/h
- Slow transfer travel at v_{max} 20 km/h
- Working travel at v_{max} 5 km/h
- Coupling travel at v_{max} 3 km/h
- Travelling/Crawling with crane operation (remote-controlled) at v_{max} 3 km/h

As both cranes of a TMV can operate completely independently of each other by radio remote control, special measures had to be taken to ensure collision safety and accident prevention when moving or crawling during crane operation.

Multiple heading with special features

The TMVs can be used in double and triple heading. A radio or cable connection ensures synchronized control. When recovering broken down underground trains, it can be useful to place a TMV at each end of the unit. The TMV at the front uses radio remote control on the TMV pushing the train. The six-car trains of the Munich underground have a total length of up to 115 metres, meaning that the transmitter and receiver of the radio signal are around 135 metres apart. The radio connection must be reliable and stable at all times in tunnels with constantly changing cross sections of different geometry and construction, in single and multi-track sections, and in curves and stations without a line of sight. For this reason, radio tests were carried out in the tunnel together with a system manufacturer as early as 2022. They were also used to precisely position the radio antenna on the vehicle.

Two coupling systems for underground and heavy haul

The Scharfenberg coupler is standard for the underground railway. Accordingly, the TMV and associated trailers are equipped with this centre buffer coupler.

Technical data	
Description	RORUNNER Level 3 E³ track maintenance vehicle
Years of manufacture	2023 – 2026
Length over couplers	20,000 mm
Total height above top of rail	3,550 mm
Axle formula	B_0‘B_0‘
Max. axle load	13.25 t
Max. payload	2x 3 t
Power at the wheelset	4x 120 kW
Operating modes	electric (conductor rail), battery-electric, diesel-electric
Conductor-rail voltage	750 V DC
Driver‘s seats	1 each/direction of travel
Perm. number of passengers	5
Smallest curve radius	70 m
Smallest hump/valley	1000 m
Max. gradient	60 ‰
Max. superelevation	165 mm
V_{max} Self-propelled travel	40 km/h
V_{max} Working travel	5 km/h
V_{max} Crawling	3 km/h
Train protection system	CTS/M 104
Couplers	Scharfenberg type 35, standard draw gear, shunting coupler type RK 55
Trailer operation	towed and pushed
Loading crane design	Palfinger PR220, 2

Tab. 1: Technical data of the Rorunner Level 3 E³

Fig. 7: Robel uses the Chiemgauer Lokalbahn line (here: Ameranger Viaduct) for testing and measuring runs in preparation for dynamic commissioning and authorization.

In addition, all vehicles for Munich are equipped with a standard draw gear on both sides including side buffers and all associated components. This allows them to move heavy-haul freight wagons on the connecting line. Four TMVs will each be fitted with an additional shunting coupler on one side. In this case, the head of the Scharfenberg coupler mounted underneath can be lowered and is moved downwards pneumatically (Fig. 6).

Continuous data acquisition, remote diagnostics and service

The TMV‘s data acquisition and recording system stores data such as battery status, operating mode, traction, and crane movements in a cloud database. The ageing behaviour of the storage cells can also be tracked in this way. This complete documentation allows evaluations, improvements, and conclusions for follow-up projects.

Digitalization also enables remote diagnostics for all operating states: manufacturers and experts from the project team and manufacturing can intervene at any time to provide support in the event of malfunctions.

Short downtimes, fast delivery of spare parts and thus increased availability are the result.

Extensive testing and preparation phase

In urban networks that operate almost around the clock, there is usually little time for detailed test runs. This means the customer wants a vehicle handed over that is ready for use as soon as possible. Although commissioning and authorization procedures cannot be shortened at will, they can be prepared by the manufacturer in the best possible way. The move to electric drive requires a completely new approach to vehicle testing and commissioning. Robel uses the independent standard-gauge infrastructure of the Chiemgauer Lokalbahn Obing - Bad Endorf line for test and measuring runs as well as for preparation of dynamic commissioning and authorization (Fig. 7)

Chiemgauer Lokalbahn

- Owner: Chiemgauer Lokalbahn e.V.
- Robel Holding has been holding a stake in the operating company since 2023
- Branch line: Bad Endorf - Amerang - Obing, single-track, not electrified
- Length: 18.5 km
- Line speed: 50 km/h
- Maximum uphill gradient: 28‰
- Use for testing, measuring, setting, and commissioning runs

Line utilization as required

It is possible to test several vehicles in parallel or use them together on this line, also in multi-shift operation. Braking, performance, and verification runs usually take place in daylight, not during a short break after midnight in which city trains aren't operating. Electric TMVs also pose new challenges for the infrastructure, as the batteries have to be recharged. The Obing terminus was equipped with charging technology which allows up to three TMVs to be charged simultaneously by cable, and the power connection of the small railway station was upgraded accordingly.
Electromagnetic compatibility and noise levels are also measured along the line.

Tests under real conditions for high vehicle maturity

The TMVs for Munich will undergo an intensive, staged test and trial phase over several commissioning cycles. This will take place on the Chiemgauer line with up to four vehicles at once. In the future, vehicle type tests to ensure function will entail more than determining measuring values. Robel focuses on involving the customer at an early stage during production, both in the factory and on the production line, in the sense of almost continuously „transparent manufacturing".

In this case, a coordinated test plan was drawn up with MVG to determine the functionality both with the infrastructure as with existing vehicles. This means that all the fundamentally relevant issues have already been dealt with prior to deployment in the Munich network; all that remains to be clarified on-site is the interaction with the train protection technology and the conductor rail. This significantly reduces the amount of work to be performed at the customer's premises. Based on the realization that, from the manufacturer's point of view, fault rectification in the test phase becomes more complex when the customer is far away, the use of the test track in Obing offers great advantages for everyone involved.

Infrastructure maintenance of the future

The switch to hybrid and all-electric modes of operation is an obligation for the entire industry. Use of a diesel engine is outdated in the city, in tunnels, and on construction sites. Further, it is no longer absolutely necessary. The new electric TMVs show that there is another way. Transport companies and infrastructure managers can profile themselves as pioneers by using electric maintenance vehicles and make a contribution to the energy and transport transition.

Martin Rudholzer
Head of Development and Design Systems & Vehicles
martin.rudholzer@robel.com

Andreas Schirmer
Director of Approval & Quality,
andreas.schirmer@robel.com

Both authors:
ROBEL Bahnbaumaschinen GmbH,
Freilassing