Optimised catenary maintenance measures on Austrian Federal Railways

The catenary systems on Austrian Federal Railways (ÖBB) generally have a high standard of quality and operating safety. To achieve and maintain this situation, it is essential to place high demands on the respective maintenance work processes for these systems. Further, increased rail traffic, together with the resulting high traffic density on the railway network of ÖBB, have called for the introduction of efficient and fast working methods in order to reduce the costs of catenary maintenance to an acceptable minimum level. The use of modern catenary maintenance vehicles cost-effectively achieves top quality work results, whilst at the same time ensuring safe working conditions, and high flexibility and work output.

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The Energy Network Division, which is part of the business sector Infrastructure of ÖBB, is responsible for the maintenance of the catenary systems. At the present time, it looks after around 9,750 km of catenary systems, which is equivalent to an electrified operating length of approx. 3,423 km (i.e. around 60% of the entire network length of ÖBB). Around 96% of all rail traffic is carried on the electrified lines.

Maintenance strategies

The network operator, as user of the catenary systems, demands minimum possible malfunctioning of the operating safety and, thus, a high availability of these systems. The technology applied in the catenary design, the systematic tracking of system disruptions, a "condition-orientated maintenance strategy", and an operating system adapted to the operational requirements, contribute substantially to the high availability that is required of the catenary systems.

Condition-orientated maintenance (Fig. 1)

The maintenance of infrastructure installations causes substantial costs every year. In view of the desired rise in productivity in the business sector, and in order to realise the goals of the management (reduction of costs), increased activities have been undertaken during the past years to reduce costs by selective planning of investment, staff and costs, thereby ensuring a fully satisfactory operating quality and no increase in the frequency of malfunctions of the catenary systems. In this respect, the previously adopted "periodical maintenance" was abandoned for "condition-orientated maintenance", thus creating the basis for a restriction of maintenance measures to only those that are absolutely necessary.

As a result of this approach of "condition-orientated maintenance", and the separation of maintenance and inspection by establishing and assessing the current actual condition, the *inspections carry special weight,* since the required maintenance measures are derived from their results. In view of their relevance for safety, time intervals for inspections have been laid down based upon the demands and the operational importance of the lines. For this purpose, the catenary systems have been divided into groups according to their importance.

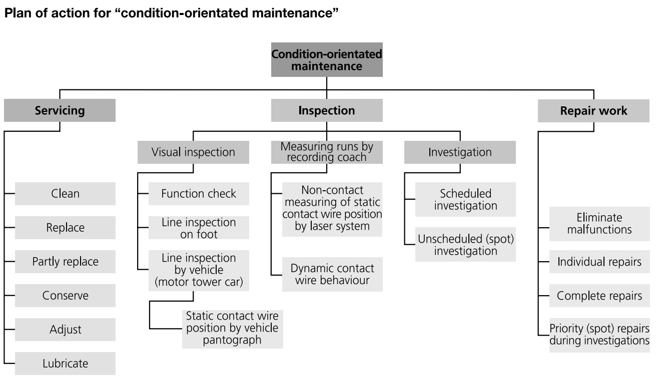

Fig. 1: Plan of action for "condition-orientated maintenance" of catenary systems on ÖBB

All efforts towards reducing the costs of maintaining the catenary systems are aimed at extending, as far as possible, the service life of the individual components of the catenary systems by applying suitable maintenance measures.

Planning of maintenance measures

The Energy Network Division of ÖBB has 22 Electrical Engineering Depots that are each responsible for the maintenance of the catenary systems within their respective maintenance region, the size of which depends, to a large extent, on the journey and access times required to perform maintenance tasks, as well as repairs in the event of malfunctions.

In order to optimally utilise the various operational possibilities in the performance of the maintenance activities, individual measures are planned selectively by the staff at the respective Electrical Engineering Depot so that, as a result of this forward-looking planning and good co-ordination of the tasks with the other business sectors, within the framework of the central planning of civil engineering work, the portion of productive time in the daily total working time can be raised considerably.

For the performance of maintenance measures on the catenary systems, the railway-specific characteristic of combining a smooth operation of train services and a cost-effective performance of work very quickly becomes the dominating cost factor. Also, the maintenance of all track-related installations, which also include the catenary systems, can only be performed during track possessions, which often produces restrictions that limit output. Thus, the overall cost-effectiveness of a maintenance measure is determined by the timing of the job, the duration and the choice of work method, and the type of traffic on the respective section of line.

From the side of the network operator, more favourable working conditions can be provided by operational measures (e.g. track closures, periodical single-line operation, replacement bus service) only when the maintenance measures are planned in advance according to *type, place, time and duration.* Assistance is offered here by a computer-based data processing technique for maintenance planning that is currently being introduced at ÖBB, within the framework of the AURA (application to support the control of resources and work deployment) project.

Performance of maintenance tasks
To assist the chosen work methods for catenary maintenance (repair, inspection and servicing), ÖBB's Energy Network Division has, over the past years, put modern vehicles, in the form of motor tower cars (MTWs), into service (in this article, a distinction is made between vehicles purely used for maintenance (motor tower cars for catenary maintenance), and those that are occasionally also used as complementary elements during catenary renewal and installation, which are referred to as motor tower cars for catenary installation and maintenance).

The vehicles used for catenary maintenance, equipped with sophisticated technology, can be tuned to specific tasks and, thus, achieve a faster progress of work and higher work output. Also for line inspection tasks and for scheduled investigations, these modern vehicles that use up-to-date diagnosis systems (measurements) are an important factor, enabling the maintenance tasks to be performed cost-effectively.

Requirements for catenary maintenance vehicles
On the basis of many years of experience with vehicles used for catenary maintenance, and after thorough discussions with the respective members of staff, the following two requirement profiles were drawn up (and have been put into practice by the procurement of vehicles meeting these requirements):

- *generally valid requirements for modern catenary maintenance vehicles (e.g. Plasser & Theurer MTW 100.064/3 (Fig. 2)).* Vehicles that are intended to efficiently perform maintenance work, safety checks and elimination of malfunctions of catenary systems, must meet the following requirements:
  - fast access (self-propelled), at V_{max} = 120 km/h, to the worksite or place of malfunction;
  - sophisticated technology to help the staff perform the tasks at hand safely and quickly. Basically, this can be ensured by:
    - a freely moving elevating work platform, from which it is possible to perform most of the work on the catenary and to support the lateral forces of the line feeders;
    - the ability to place the freely moving elevating work platform on the vehicle frame between the workshop and the crew cabin;
    - devices to assist the work processes (including, for instance, supporting the lateral forces of contact wire and carrying cable);
    - remote control options via radio for vehicle and equipment;
    - devices to check the position of the contact wire during the regulating process, and to inspect the position of the contact wire under approximate operating conditions;
    - a laser scanner to increase the safety of staff working in the track area directly in front of the MTW who, when the vehicle is controlled from the area between the workshop and crew cabin, are not in the visibility range of the vehicle operator;
- *additional requirements for catenary installation and maintenance vehicles (e.g. Plasser & Theurer MTW 100.013/2 (Fig. 3)).* Vehicles that are intended to also perform catenary assembly work must, additionally, meet the following requirements:
  - sophisticated work technology, complemented by:
    - the placement of the freely moving elevating work platform on the cabin roof;
    - a loading crane for handling heavy loads (e.g. masts, supports, cable drums, and other heavy fittings);
    - the ability to reach not easily accessible areas (e.g. line feeders) from a secured workplace (e.g. using work basket);
    - the ability to optically inspect, as well as to measure and record, the (static) contact wire position.

Also, the pertinent European norms with respect to the transport and the operation of rail-bound machines and the threshold values for pollutant emissions of the power units have to be taken into account.

Fig. 2: Plasser & Theurer MTW 100.064/3 Motor Tower Car for catenary maintenance

Fig. 3: Plasser & Theurer MTW 100.013/2 Motor Tower Car for catenary installation and maintenance

Characteristics of the catenary maintenance vehicles

On all vehicles, the drive unit is positioned underfloor so that virtually the entire space above the vehicle frame is available for the cabin(s) and various equipment:

— *motor tower cars for catenary maintenance (Fig. 2):* these vehicles feature two separate cabins, a workshop and a crew cabin, each with a driver's control desk, which enables the freely moving elevating work platform to be placed on the vehicle frame. This facilitates access to the work platform and, thus, increases safety during work. A single 8-cylinder diesel engine, featuring 381 kW output at 2100 rpm, functions as both the driving and working engine;

— *motor tower cars for catenary installation and maintenance (Fig. 3):* these vehicles feature, apart from the space to position and operate the hydraulic loading crane, a large enclosed cabin covering nearly the entire frame area. The interior of the cabin features a driver's control desk, a workshop compartment with recording desk, and a crew room (for at least six persons) with a driver's control desk. The vehicles feature two engines: a 12-cylinder diesel engine, featuring 367 kW output at 2300 rpm, which functions as the driving engine, and a 4-cylinder diesel working engine, featuring 74 kW output at 2300 rpm.

As both engines are equipped with hydraulic pumps, it is possible to work with either the driving engine or the working engine (with the exception of the crawling gear which requires the operation of the working engine).

Fig. 4: Driver's desk with operating controls and display

The operation and work sequences of both types of vehicle are program-controlled, with the driver's control desks equipped accordingly. Thus, errors in operation are, to a large extent, excluded. On the motor tower cars for catenary maintenance, the program control is complemented, at the operator's desk, by a monitor featuring a text display that clearly lists the work and malfunction situations (Fig. 4).

Fig. 5: Plasser & Theurer MTW 100.013/2 Motor Tower Car for catenary installation and maintenance, with freely moving elevating work platform and loading crane featuring work basket

Freely moving elevating work platform

Both the motor tower car for catenary maintenance and that for catenary installation and maintenance feature a freely moving elevating work platform, controlled fully hydraulically, which represents a significant innovation for these types of vehicle. On the motor tower car for catenary maintenance, the work platform can be accessed from the work platform between the two cabins (Fig. 2). On the motor tower car for catenary installation and maintenance, on which it is positioned on the roof, it can be reached from the crane platform via a ladder (Fig. 5).

The freely moving elevating work platform enables work to be carried out at up to 15.5 m over top of rail, up to 4.0 m below top of rail, and up to approx. 4.5 m to either side of the track axis (Fig. 6). Vehicle stability in unsupported state is guaranteed, even in the case of a track superelevation of up to 150 mm. Using additional side supports, the lateral range is extended to 13 m.

The work platform is positioned on a specially developed folding and extending jib construction. Thus, even a displaced catenary is no longer a hindrance; the work platform is not locked in under the contact wire, as is the case with conventional elevating column designs. Thanks to electro-hydraulic level control of the platform, work can be performed in a virtually always horizontal position (with a permissible tolerance of ±5°).

The slewing system of the work platform, which features an endless design, is dimensioned in such a manner that, besides the loading capacity of 400 daN, also pulling or pushing forces of up to 350 daN can be taken up (e.g. lateral forces of line feeders). The work platform itself can be rotated horizontally by ±90° or ±75°, depending on the position of the jib. Using the vehicle weight and a built-in slewing angle limitation, the full loading capacity is available up to ±35.8° to the left and the right of the vehicle axis.

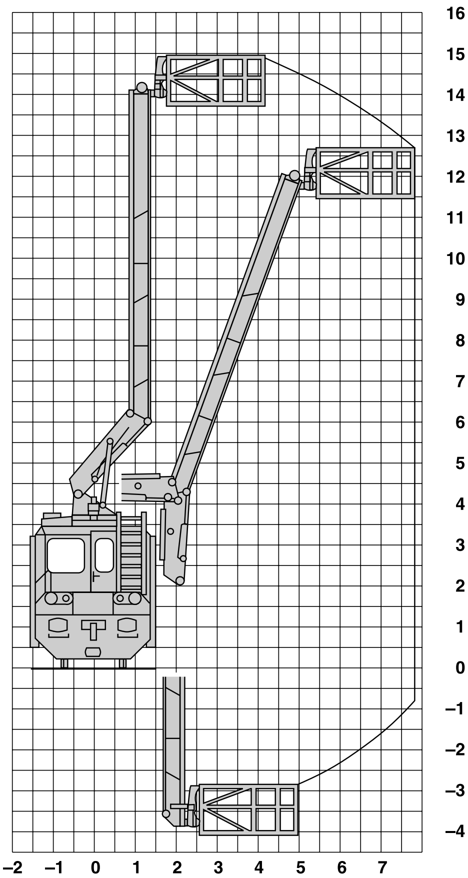

Fig. 6: Range of movement of the freely moving elevating work platform

The work platform is equipped with tool rests (an enclosed cupboard and open shelves), non-glare lighting, sockets for electrical appliances and a pneumatic connection. It is possible to plug in telescopic halogen spotlights, and there are holding units for earthing rods. The lateral forces mentioned previously are taken up by fold-up sliding arms with claws. There is also a contact wire resting roller which, if necessary, can be placed in working position.

Hydraulic loading crane and work basket

The motor tower car for catenary installation and maintenance features a hydraulic loading crane (Fig. 5), which has a lifting capacity of 220 kNm and a working range of up to 22 m over top of rail, and up to 16.7 m sideways. The crane is fitted with a special dual pressure system which, in the low pressure range, enables accurate manoeuvring of loads when travelling at crawling speed, which is especially important when the work basket is in use. In the high pressure range, it enables the handling of nearly all conventional loading situations during catenary maintenance. For instance, the moving of about 50% of all catenary supports and masts, the mounting of mast transformers, the loading of cable drums, etc.

It is also worth mentioning that the crane features two built-in overload safety devices, which ensure vehicle stability even when there is an excess load.

The work basket that can be attached to the hydraulic loading crane is of particular importance for the performance of work in a safe environment. From the work basket, it is possible to carry out work up to a height of approx. 22 m (Fig. 5), thus the tops of almost all catenary masts in use on the ÖBB network can be reached from the work basket, without having to climb on them. The work basket has a maximum loading capacity of 280 kg. This, in most cases, is sufficient, as no more than two workers with tools and relatively light assembly material need to be transported.

Cable holding units

Two identically designed hydraulically operated cable holding units, one for the contact wire and the other for the carrying cable, are mounted on the cabin roofs (3.55 m over top of rail) — on the motor tower car for catenary maintenance, behind the earthing pantograph and, on the motor tower car for catenary installation and maintenance, directly behind the measuring pantograph. Both cable holding units can be moved, at their base, by 0.65 m to the left or to the right from the vehicle centre. Thus, depending on the work situation, they can be placed in working position on both sides of the catenary suspension, thereby achieving a working height of 4.90 m to 8.50 m over top of rail. All lateral and vertical forces occurring in the area of the catenary suspension can be taken up by the cable holding units.

The most striking example of application of the cable holding units is during the exchange of insulators on a bracket, or the replacement of a bracket itself (Fig. 7). Considering the conditions under which such work had to be performed up to now, these devices substantially *increase the speed and safety* of these tasks.

Radio remote control

Radio remote control is available for the freely moving elevating work platforms, the loading cranes and the cable holding units. For safety reasons, the controls of the elevating work platforms and of the loading cranes are equipped with dead-man handles, in order to prevent possible malfunctions, such as inadvertently moving a control stick when putting down a tool.

The radio remote controls operate independently of each other. For safety reasons, each of the systems is equipped with an *emergency stop button,* which shuts down all functions of the respective motor tower cars (engine emergency stop and braking).

The crawling gear functions of both types of vehicle can be controlled by the radio remote controls of the elevating work platforms and the loading cranes.

Fig. 7: Cable holding unit in operation during bracket work

Laser scanner

When operating the motor tower car for catenary maintenance from the work platform between the workshop and crew cabin, the track area directly in front of, or behind, the vehicle cannot be seen by the operator due to the vehicle layout. In order to cover this blind spot, a laser scanner is mounted at both ends of the vehicle (Fig. 8).

Fig. 8: Laser scanner (between the headlights) on the MTW 100.064/3 Motor Tower Car for catenary maintenance

The laser scanners, which react to different response distances, are adjusted in such a manner that, in the detection range of the scanner from 5.0 to 3.0 m, a warning signal will sound automatically - in addition to the intermittent warning tone which sounds when travelling at crawling speed. If the motor tower car comes within 3.0 m of a detected obstacle, the vehicle's emergency brake will automatically be activated, thus ensuring that no harm comes to staff or obstacles present in that area.

Earthing pantograph
On the motor tower cars for catenary maintenance, the earthing pantograph is positioned and earthed on the roof of the crew cabin (Fig. 2). To measure the height of the contact wire over top of rail under "dynamic" conditions, the contact pressure of the earthing pantograph can be adjusted steplessly from 50 to 150 N, using a pneumatic pressure reducing valve. The height and stagger of the contact wire must still be observed by one of the crew.

On the motor tower cars for catenary installation and maintenance (Fig. 3), the earthing pantograph is positioned and insulated on the cabin roof, over a bogie. To measure the height of the contact wire over top of rail under "dynamic" conditions, the contact pressure of the earthing pantograph can, on these vehicles, also be adjusted steplessly. Also, measuring can be done on live catenary at a speed of up to 60 km/h. The height and stagger of the contact wire are recorded by a video system and can, thus, be observed on a monitor.

The earthing pantographs on both types of vehicle are controlled by a pneumatic circuit breaker, positioned on the vehicle roof, which is switched by the program control of the vehicle. A deliberate, registered, actuation of the earthing switch can be made via a key switch.

Measuring pantograph
The motor tower cars for catenary maintenance are fitted with a hydraulically adjustable measuring pantograph, positioned directly behind the earthing pantograph, which serves to set a defined contact wire height over top of rail in order to regulate the contact wire.

The measuring pantograph on the motor tower cars for catenary installation and maintenance, also positioned directly behind the earthing pantograph, fulfils two functions. On the one hand, it can measure the "static" contact wire position, using a contact pressure of only 5 N, when travelling at crawling speed and, on the other, it is able to set a defined contact wire height over top of rail in order to regulate the contact wire (in both cases, the axle springs of the bogie, located under that side of the vehicle where the pantograph is positioned, are blocked against the vehicle frame by hydraulic cylinders, thus producing a defined position of the measuring pantograph).

The measurements can only be carried out in an "earthed" state. For recording the "static" contact wire position, as well as the lateral deflection of the contact wire, which is performed by the aforementioned video system, proximity switches are mounted on the contact strip of the measuring pantograph.

For the "static" measurement, the measuring pantograph is controlled by a hydraulically operated scissor-type lifting device, complemented by a pneumatic cylinder which, in an area of approx. ±25 mm, presses the contact strip with a constant force onto the contact wire using integrated, inductive switches.

Video system
The aforementioned video system on the motor tower cars for catenary installation and maintenance consists of a video camera mounted on the crane arm of the freely moving elevating work platform, a long-time recorder located at the measuring desk in the workshop compartment, and a control monitor.

The video system is complemented by the various pneumatic switches, proximity switches and measuring transducers of both the earthing and the measuring pantographs.

On the pictures supplied by the video camera, the monitor shows the kilometre position (indicated and automatically inserted via the transducer of a Hassler tachograph) and the contact wire height, and then makes a recording.

Display unit for dropper installation
The display of the contact wire height also includes a "dropper measuring display", which allows the distances between the droppers to be displayed while the vehicle is moving.

The distance information is entered via a keyboard and processed, while the vehicle is in motion, by the aforementioned transducer of the Hassler tachograph, also showing the direction of travel. Thus, the rough measurement using a yard stick is no longer necessary for dropper installation.

Conclusions
A well-targeted maintenance management for catenary systems applies clear concepts for the maintenance strategy and the deployment of modern vehicles. This also includes proven instruments, such as work preparation, early planning and co-ordination of the maintenance measures, as well as informative and up-to-date documentation. The maintenance strategy for catenary systems adopted by ÖBB's Energy Network Division, presented in this article, aims to achieve *minimisation of the maintenance costs*, whilst ensuring *maximum operating reliability* of the catenary systems.

With the measures and work methods that have been employed on ÖBB for several years now, it has been possible to introduce an optimised, constant quality of work and, thus, a significant increase in service life and more favourable catenary maintenance intervals.

Thus, adopting the work processes developed by ÖBB's Energy Network Division and using the modern catenary maintenance vehicles, supplied by Plasser & Theurer, have led to the cost-effective achievement of top quality work results, whilst at the same time ensuring safe working conditions, and high flexibility and work output, thus greatly enhancing the operating reliability and availability of the catenary systems.