Installation, renewal and maintenance of overhead catenary systems by means of a specially designed catenary installation and renewal machine

Increased demands on the quality, reliability, operating safety and availability of overhead catenary systems for high-speed and high-capacity railway lines have altered the planning parameters and, consequently, the strategies for installation and maintenance. Also, in view of cost reductions and the shortening of installation times, optimised working procedures for catenary installation have been developed, resulting in new requirement profiles for modern work machinery. This article looks at a specially designed catenary renewal and installation machine that meets these requirements.

By: Dipl.-Ing. Manfred Irsigler, Former Head of Business Unit Energy at Austrian Federal Railways (ÖBB), currently Lecturer at the Technical Universities of Vienna and Graz, Austria & Ing. Johann Kohel, Former Staff Member responsible for Development & Procurement of catenary installation and maintenance vehicles, ÖBB.

FRAMEWORK CONDITIONS FOR CATENARY INSTALLATION MACHINES

New types of overhead catenary - especially for new and upgraded lines of the trans-European railway network according to plans of the European Commission (EC) [1] - are subject to new planning, dimensioning and quality requirements as per Directive 2004/50/EC [2], the associated Technical Specifications for Interoperability (TSIs) [3], the new European Standards EN 50367 [4] and EN 50388 [5], the Standard EN 50119 [6], as well as recommendations of the International Union of Railways (UIC). The intended upgraded speed determines the design of the overhead catenary system, requiring high tensile stresses, uniform elasticity and low tolerances in the contact-wire position, the change of gradient and the tensional forces. Also, the specifications for the contact forces between contact wire and pantograph(s) must be observed.

High operating safety, long service life and, therefore, low life-cycle costs are the objective. Accuracy during installation, so that a consistently high quality is ensured, has a great influence on these parameters. This high quality is achieved by overhead catenary systems that are easy to assemble and maintain, coordinated assembly technologies using appropriate equipment and machines, as well as the skills of the assembly team.

The specifications concerning the installation of contact wires and carrying cables require that:

- the contact wire must be rolled out from the storage drums undamaged, neither twisted nor deformed, with the nominal tension of that type of wire, and be guided to the installation points at the brackets. This demands an exact control of the drums, as regards torque and lateral position, as well as guidance of the contact wire and carrying cables by the installation machines;
- a fine control of the nominal tension over several winch wheels is necessary, particularly in the case of the high tensile stresses required for high-speed catenary systems;
- the nominal tensional forces must be kept within tight tolerance limits, even in the sensitive work phases during starting and stopping of the installation work;
- in view of the contact wires with a 120 to 150 mm^2 cross-section and the high-strength alloys, the demands on the quality of installation can only be met cost-effectively by using mechanised methods and combined work processes.

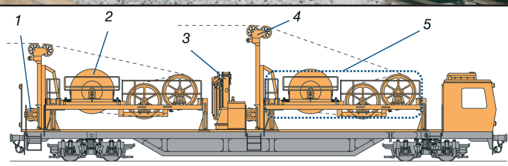
These requirements are met, for instance, by the Plasser & Theurer catenary installation and renewal machine of the latest generation that is addressed in this article.

CATENARY INSTALLATION AND RENEWAL MACHINE OF THE LATEST GENERATION

Swedish State Railways (Banverket) was the first company to develop, together with Plasser & Theurer, the technical concept for a catenary installation and renewal machine (FUM) [7], [8], [9], [10], [11].

The catenary installation and renewal machine of the latest generation: a description

The Plasser & Theurer catenary installation and renewal machine (FUM) of the latest generation is fitted with telescoping lifting masts with roller heads, as well as two independently controlled tilting winch tables, each featuring four friction winch wheels, at least three of which are hydrostatically powered, and hydraulically powered storage drums for contact wires and carrying cables (Fig. 1). Furthermore, the machine is equipped with a work crane and additional cable winches located at the lifting masts that are used, for instance, for removing contact wires and carrying cables from the storage drums via the friction winches.



1: cable winch 2: storage drum 3: work crane
4: telescoping lifting mast with roller heads
5: winch table with friction winch

Fig. 1: The Plasser & Theurer catenary installation and renewal machine of the latest generation

The friction winches adjust the required tensional forces steplessly and hold them at a constant tension. Contact wires and carrying cables are pulled from the storage drums via the friction winches and the roller heads of the lifting masts, and placed in the assembly position with the required tension. The lifting masts are tilted with the turning movement of the winch tables, in order to avoid any twisting of contact wire and carrying cable. Additionally, the storage drums are laterally displaceable in the tilting frame, so that contact wire and carrying cable run into the friction winches in a straight line. This produces the necessary accuracy of assembly and avoids permanent deformations of the contact wire.

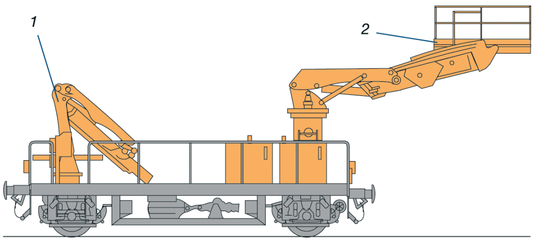
For a high-quality assembly, it is decisive that the selected installation tensional force is held constant in all situations during operation. Critical situations are the transitions from standstill of the unit to the assembly speed, and vice versa. The demand for a constant installation tensional force is met by the hydrostatic drives, in conjunction with the automatic start-up control. The vehicle and friction winch brakes are not released by a central computer until the selected tensional force is neutralised by the drive oil pressure.

All machine operations are controlled either automatically or manually via remote control, so that the machine operator can operate the catenary installation and renewal machine even in unusual assembly situations.

All relevant machine data and measuring data of installation, such as nominal and actual tensional forces, are recorded with the help of a central computer and secured as a document in a reproducible format, so that it can be established that the required installation criteria have been observed.

For preparatory and follow-up work, the catenary renewal and installation machine (FUM) is complemented by:

— *a self-propelled hydraulically powered assembly car - AW (Fig. 2),* which features a freely turning elevating work platform on an endless rotating column and a loading crane. The working range of the elevating work platform enables work to be performed - from a secure standing position for the assembly personnel - up to 16 m over top of rail and 8 m laterally from the track axis, without any additional supports. Moreover, the work platform, which has a load capacity of 8 kN and features automatic levelling, can also be slewed ±90° laterally and withstand horizontal forces of 3.5 kN. All operations, such as movements of the elevating work platform or driving, are controlled by radio remote control;



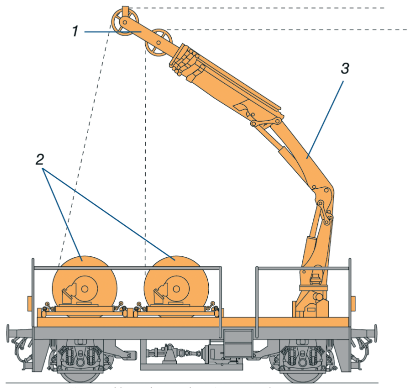
1: loading crane 2: elevating work platform

Fig. 2: Diagram of the assembly car (AW) with freely turning elevating work platform

— *two-axled assembly tower cars - MGW (Fig. 3),* which are equipped with three independently-controlled column elevating work platforms. The middle work platform can be reached by an automatic telescoping ladder. The two side work platforms have a working range of up to 9.0 m over top of rail and 4.5 m laterally from the track axis, without any additional supports. The central platform can carry 5 kN, and the side platforms 2.5 kN each. The assembly tower cars are equipped for conducting work on the catenary systems (e.g. brackets and current connectors), and on the masts (e.g. brackets, rigging and earthing);

Fig. 3: Assembly tower cars (MGW) with three independently-controlled column elevating work platforms

— *cable winch cars - FWW (Fig. 4),* which are equipped with two hydraulically powered cable winches and a work crane that is used to pull the existing catenary over a roller head, which is then wound up at a reduced tensional force (approx. 3.0 kN) on storage drums. The storage drums are guided independently in axial direction, so that contact wire and carrying cables are wound up layer on layer. The work crane is also used for lifting the storage drums;



1: roller head 3: work crane
2: winches for cable drums

Fig. 4: Diagram of the catenary winch car (FWW)

— *a motor tower car - MTW (Fig. 5),* which features an elevating work platform, a work crane, a contact wire and carrying cable holding device, as well as a contact wire measuring system. The freely-turning elevating work platform, which features automatic levelling, can be slewed laterally by ±90°. With a working range of up to 16 m over top of rail and 8 m laterally from the track axis, the work platform allows the personnel to reach all points on the catenary system from a safe location. In all normal assembly situations, the contact wire and carrying cable holding device can withstand the vertical and lateral forces of wires and cables, and hold them in position or place them into a new one. The work crane, which is used for moving heavy loads, such as cable drums, fittings, etc., can also be fitted with a work cage.

Fig. 5: Motor tower car - MTW (above) with contact wire and carrying cable holding device (left) and measuring pantograph with proximity sensors (below)

The computer-controlled safe-load indicator guarantees the stability of the machine for most work situations without any additional supports, even when the elevating work platform is extended and the work crane is active at the same time. With regard to work safety, the assembly equipment and the travel movements are performed almost jolt-free. The machine operations can be controlled by a remote-control unit, either directly from a workplace, the work platform, or from outside the vehicle.

Using the measuring pantograph (Fig. 5), the position of the contact wire can be measured and recorded almost without load, as well as under the influence of adjustable contact forces. The resting position is measured with a contact force of 5-10 N at a maximum travelling speed of 5 km/h. The contact force can be set at up to 250 N to simulate the passage of the pantograph in normal service, and to check the rise at critical spots, such as steady arms, switch connectors and overlapping points. Proximity sensors on the measuring pantograph measure the stagger of the contact wire.

WORK PROCESSES

The work processes performed by the catenary installation and renewal machine, together with the other vehicles, are described using a sample catenary section (Fig. 6).

Exchange of contact wire only

Fig. 7 shows the positioning of the vehicles for the exchange of contact wire only, which is carried out in a single track possession.

In this example, the work is performed as follows:

— the assembly tower car (MGW) operated by two men and the cable winch car (FWW) with one man are assigned to remove droppers, connectors and fixed-point anchors, and to roll up the contact wire being replaced;

— the catenary installation and renewal machine (FUM) operated by one man and the assembly car (AW) with two men put up the new contact wire with the nominal tensional force required, clamping it to the masts and the droppers. This work begins already during the removal of the old contact wire. To allow the contact wire to be clamped in the tensioning devices, it is pulled from the cable drum by an auxiliary cable using a cable winch, pulled to the terminating mast and then led back from there over a deflecting roller. Then, the cable winch pulls the contact wire, using the auxiliary wire, to the terminating mast where it is connected;

— two men standing on the motor tower car (MTW) carry out the finishing jobs, such as pressing the current and equalising connectors, fitting the insulators, replacing defective components, installing fixed-point anchors, checking the contact wire position;

— after completion of the work at the end of the section, the position of the new contact wire can be measured and recorded on the return journey.

After approx. 3.5 hours of working time, the exchange of the contact wire is completed and the line can be re-opened for traffic.

Each stage of work and the time required is shown in the time/travel graph depicted in Fig. 8.

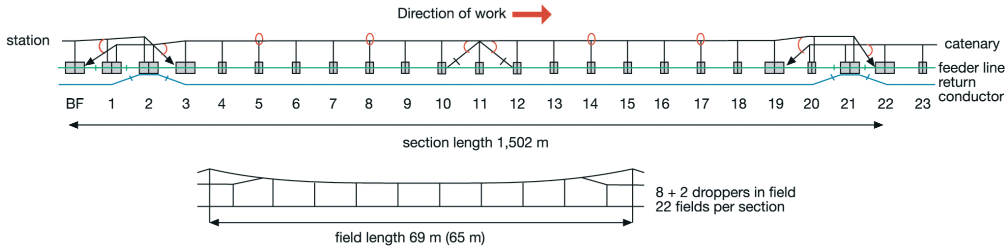
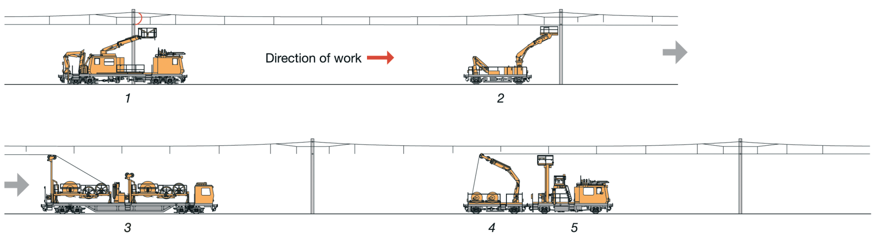
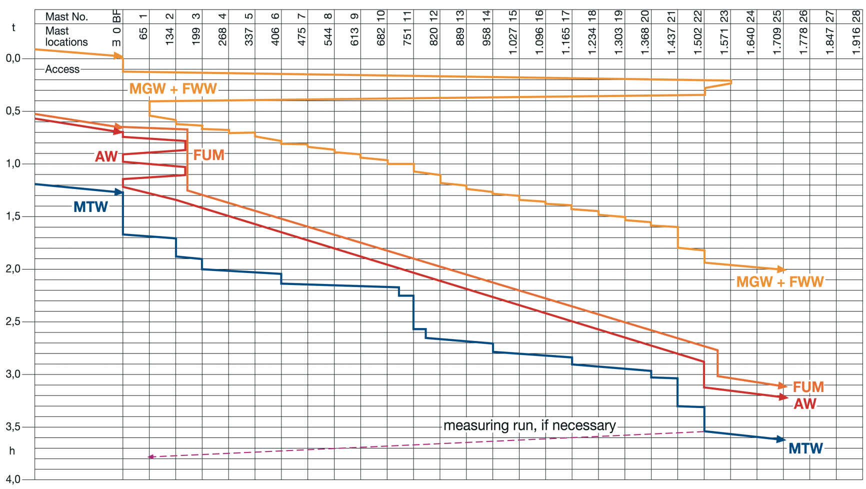


Fig. 6: Example of a section of overhead catenary system



1: motor tower car (MTW)
2: assembly car (AW)
3: catenary installation and renewal machine (FUM)
4: cable winch car (FWW)
5: assembly tower car (MGW)

Fig. 7: Positioning of the vehicles for the exchange of contact wire only



MGW + FWW: earthing and fixing pulley tensioning unit, both station and line side; removal of droppers, current and equalising connectors, fixed-point anchors, contact wire is threaded into FWW, contact wire unclamped at the masts; winding of contact wire is monitored at the FWW.

AW: contact wire is clamped in at the masts, droppers are mounted.

MTW: current connectors and equalising connectors are pressed in, insulators are connected, fixed-point anchors are mounted.

FUM: the new contact wire is installed.

Fig. 8: Time/travel graph for the exchange of contact wire only (abbreviations used are explained in the text)

Renewal of an entire catenary system

When renewing an entire catenary system, it is necessary to dismantle first the old catenary system and then to assemble the new one.

Catenary removal (Figs. 9 and 10)

For removing the old catenary system, two men on the first assembly tower car (MGW) carry out the earthing, the locking of the tensioning devices, and the removal of the droppers, connectors and anchors.

Two men on the second assembly tower car (MGW) unclamp the contact wire and carrying cables and remove the stitch wires.

Two men on the third assembly tower car (MGW), together with the cable winch car (FWW), remove the old catenary system.

Each stage of work during removal is shown in the time/travel graph depicted in Fig. 10.

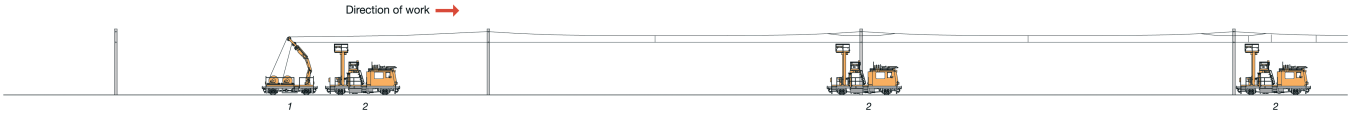


Fig. 9: Positioning of the vehicles for the removal of the old catenary system 1: cable winch car (FWW) 2: assembly tower car (MGW)

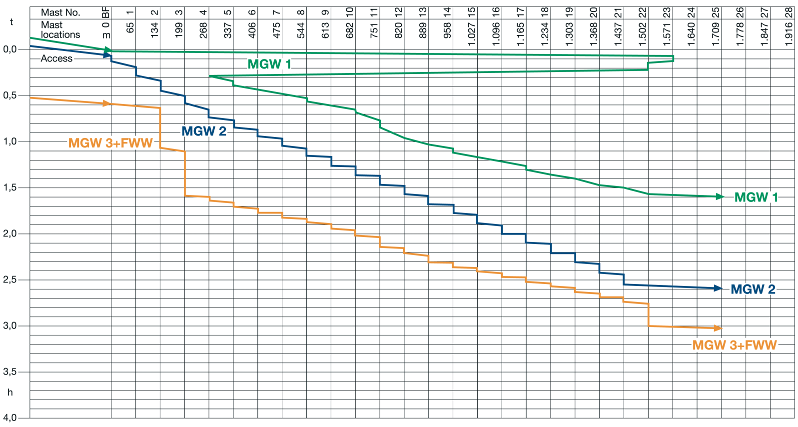


Fig. 10: Time/travel graph for the removal of the old catenary system (abbreviations used are explained in the text)

MGW 1: earthing on line-side, pulley tensioning unit is locked, removal of droppers, current connectors and equalising connectors, fixed-point anchors.
MGW 2: earthing on station-side, pulley tensioning unit is locked, carrying cable holders are opened and contact wire is unclamped; stitch-wire suspensions and current connectors are unclamped.
MGW 3 + FWW: removal of complete catenary system and fixed-point cable.

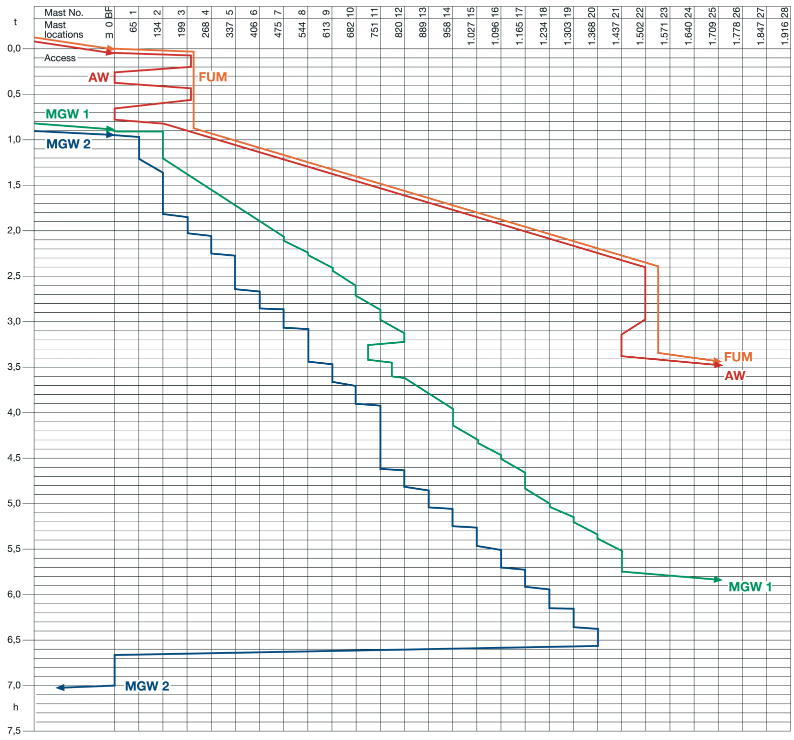


Fig. 11: Time/travel graph for the installation of the new catenary system (abbreviations used are explained in the text)

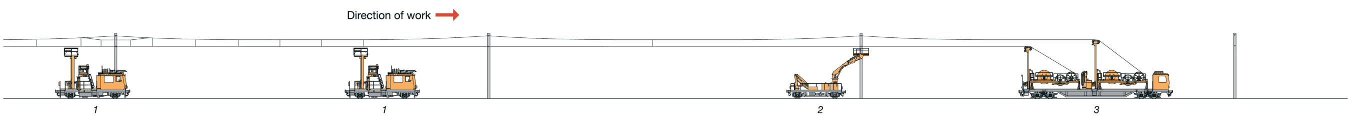
Catenary installation (Figs. 11 and 12)

The catenary installation and renewal machine (FUM), operated by one man, simultaneously installs the new contact wire and carrying cables, which are fixed on the masts by two men on the assembly car (AW). Two men on the assembly tower car following behind align the brackets and install the droppers, fixed-points and current connectors. Two men on the second assembly tower car install the stitch wires and feeder lines, and adjust the tensioning devices. Each stage of work during installation is shown in the time/travel graph depicted in Fig. 11.

In the same way as for the exchange of contact wire only, the position of the new contact wire can be measured and recorded on the return journey.

Approx. three hours are required to remove the old catenary system and about seven hours to assemble the new one. When removal and installation work are streamlined by combining the two operations, it is possible to re-open the track for traffic after about 8.5 hours.

FUM: installation of contact wire and carrying cable.
AW: positioning of contact wire and carrying cable at supports, attaching of pulley tensioning unit at line-side, mounting of some current connectors.
MGW 1: preparation of brackets; assembly of droppers, fixed-point cable, fixed-point anchors, mounting of some current connectors.
MGW 2: installation of stitch-wire suspensions; mounting of feeder lines and some current connectors; on station-side, pulley tensioning unit is connected.



1: assembly tower car (MGW) 2: assembly car (AW) 3: catenary installation and renewal machine (FUM)

Fig. 12: Positioning of the vehicles for the installation of the new catenary system

CONCLUSIONS

The method described has several benefits, in that it brings:

— *a reduction in costs:* the continuous working method enables high working speeds and, thus, output to be achieved. Thanks to the machine technology, the automation and the remote control operation, only a few specialists are required; this reduces the assembly costs. Forward-looking planning and worksite preparation, as well as short set-up/dismantling times and fast transfer travel of the machine and vehicles to/from the worksite reduce additional operating costs;

— *an extension of the service life:* the installation of the contact wire with the final tensional force saves the phase of wire stretching, and also a more accurate regulation is achieved. Also, no further adjustment and follow-up jobs are needed. The uniform and careful unrolling of the contact wires avoids deformation and waviness in the contact wire surface. The mechanised and continuously monitored installation and positioning ensures the quality of the contact wire and carrying cable position, which can be checked with the help of the recordings, thus extending the service life;

— *a reduction in operational hindrance costs:* mechanised methods lead to shorter line occupation. After completion of the work, the line can be re-opened for traffic without restrictions. Costs for journey time losses, speed restrictions, braking and accelerating the trains, as well as for additional energy requirement are reduced significantly;

— *a reduction in track possessions:* using the described method of work, regardless of the composition of the work train, track closure times can be reduced by about 50% and the number of staff required by up to 60%. Therefore, the work costs are lowered considerably as compared to using conventional methods of installation;

— *a good rate of return on investment:* the investments for a coordinated machine range that fulfils all tasks of installation and renewal, maintenance and malfunction management can pay for themselves in five to seven years. If a modern machine fleet of motor tower cars is already available, the addition of a catenary renewal and installation machine can provide a rate of return on investment in three to four years.

In short, using the method described in this article an excellent production output can be achieved, with observance of the required standard of quality and criteria for safe working. It enables fast, accurate and cost-effective installation and renewal of overhead catenary systems.

REFERENCES

[1] Decision No. 2004/884/EC: ‘Decision amending Decision No. 1692/96/EC on Community guidelines for the development of a trans-European transport network', Official Journal of the European Union 2004, EN L167/1-L167/38.

[2] Corrigendum 2004/50/EC: 'Corrigendum amending Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC on the interoperability of the conventional trans-European rail system', Official Journal of the European Union 2004, EN L220/40-L220/57.

[3] Decision No. 2002/733/EC: ‘Technical specifications for interoperability (TSIs) relating to the energy subsystem of the trans-European high-speed rail system referred to in Article 6, Paragraph 1 of Directive 96/48/EC’, Official Journal of the European Union 2002, EN L245/280-L245/369.

[4] EN 50367:2005: ‘Railway applications - Current collection systems - Technical criteria for the interaction between pantographs and overhead line to achieve interoperability’.

[5] EN 50388:2005: ‘Railway applications - Power supply and rolling stock - Technical criteria for the coordination between power supply and rolling stock to achieve interoperability’.

[6] EN 50119:2001: ‘Railway applications - Fixed installations - Electric traction overhead lines’.

[7] Thylén S., Lundin L.: ‘New method of installation and renewal of overhead catenary systems in operation in Sweden’, Rail Engineering International, Edition 1991, Volume 20, No. 1.

[8] Fels W.: ‘Fahrleitungsbaufahrzeuge’, Elektrische Bahnen, No. 12/1998.

[9] Schneider B., Wagner E.: ‘Mechanisierte Oberleitungsmontage bei den SBB’, Der Eisenbahningenieur, No. 2/1998.

[10] Wenty R.: ‘Maschinen für Fahrleitungsbau und -instandhaltung’, ETR-Eisenbahntechnische Rundschau, No. 1-2/2000.

[11] König W., Michalski U.: ‘Innovative catenary installation technology applied on German Rail’, Rail Engineering International, Edition 2004, Volume 33, No. 2.