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Maintenance guidelines for overhead contact lines

Prescriptions relatives à la maintenance des caténaires
Instandhaltungsrichtlinien für Oberleitungen

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Contents

Summary

This document was prepared in the UIC Infrastructure Forum by the Traction and Energy Experts Group to provide Infrastructure Managers (IM) with guidelines for maintenance of overhead contact lines (OCL) based on uniform criteria and common objectives.

OCL have been divided into their main components or parts to be taken into account for planning and performing maintenance operations.

At the same time the main parameters to be checked, measured or observed and the operations/ interventions to be carried out have been identified, as well as the data that should be examined to evaluate the condition of the OCL and to ensure expected performance.

1 - General

1.1 - Scope

These guidelines relate to the activities to plan and perform in order to maintain the characteristics of overhead contact lines (OCL) at the levels expected to guarantee the performance required for the relevant railway lines.

1.2 - References

(see Bibliography - page 88)

1.3 - Field of application

This leaflet sets out guidelines to ensure the best maintenance of all OCL fed both in DC or in AC current, under different traffic conditions, speeds, etc.

The leaflet can be applied in particular to maintain OCL systems operating at the following voltages:

- 1,5 kV and 3 kV DC;
- 15 kV – 16 2/3 Hz;
- 25 kV – 50 Hz.

2 - Definitions

The main definitions below refer not only to the characteristics of OCL but also to other parameters concerning traffic density, line speed, environmental conditions, etc.

2.1 - General

Energy system
All the electrical installations needed to supply an electric traction network including sub-stations, contact lines, return circuit and pantographs, as set out in the Technical Specifications for Interoperability (energy sub-system - see Bibliography - page 88).

Electric traction lines
Electric lines equipped to transmit electric power from sub-stations to trains.

Electro dispatching
A central site equipped for remote command and control of electric traction installations from where shift operators control the energised state of installations and authorise their switching off at the request of the OCL personnel.

Overhead line
Electric line consisting of conductors supported above ground by means of insulators and appropriate supports.

Contact line
Conductor system to supply electrical energy to vehicles through current collection equipment.

Overhead Contact Line (OCL)
Contact line placed above the upper limit of the vehicle gauge and supplying vehicles with electrical energy through pantographs.

OCL with catenary suspension
OCL where the grooved contact wires are suspended from one or more longitudinal catenaries.

Tensioned OCL
OCL in which the mechanical tension of the conductors (catenaries and contact wires) is kept automatically constant within certain temperature limits.

Semi-tensioned OCL
OCL in which the mechanical tension of the contact wires is kept constant automatically within certain temperature limits.

Fixed (non-tensioned) OCL
OCL not equipped with automatic tensioning devices.

Compound OCL
OCL with one or two contact wires suspended from an auxiliary catenary which is suspended from the main catenary.

OCL stitch catenary suspension (Y)
OCL equipped with stitched catenary suspension.

Item
Any part, component, device, sub-system, functional unit, equipment or system (consisting of hardware, software or both) that can be considered individually.

Failure
The termination of the ability of an item to perform a required function. After failure, the item has a fault. "Failure" is an event, as distinguished from "fault" which is a state.

Fault
The state of an item characterised by the inability to perform a required function, excluding the inability during preventive maintenance or other planned actions, or due to lack of external energy supply.

Transient fault
A fault of an item which persists for a limited time duration following which the item recovers the ability to perform a required function without being subjected to any corrective maintenance action.

Permanent fault
A fault of an item that persists until a corrective maintenance action is performed.

Manufacturing failure (manufacturing fault)
A failure (fault) due to non-conformity during manufacture to the design of an item or to specified manufacturing processes.

Design failure (design fault)
A failure (fault) due to inadequate design of an item.

2.2 - Conductors

A conductor is a metal wire or cable, either solid or stranded, designed to carry electrical energy and forming part of the OCL system.

Catenary
Longitudinal wire supporting the grooved contact wires either directly or indirectly.

Main catenary
Catenary supporting an auxiliary catenary by means of droppers.

Auxiliary catenary
Catenary suspended from the main catenary and supporting the grooved contact wires directly by means of droppers.

Stitch catenary suspension
Catenary suspension in which the contact wire is suspended by one or more droppers from a short continuous auxiliary wire, attached to the main catenary at one point on each side of the main catenary support.

Stitch wire
The auxiliary wire used in stitched suspension.

Contact wire
Electric conductor of an OCL with which the current collectors make contact.

Feeder
Electrical connection between the contact line and the sub-station or the switching station.

Line feeder
An overhead conductor installed parallel to the contact line, either to supply successive feeding points or to increase the useful cross-sectional area.

Reinforcing feeder
Overhead conductor installed adjacent to the OCL and directly connected to it at frequent intervals in order to increase the effective cross-sectional area.

Fixed termination conductor
A conductor on which the tension is not regulated by an automatic tensioner.

Auto tensioned conductor
A contact wire or catenary in which the mechanical tension is regulated by an automatic tensioner.

2.3 - Electrical

Nominal voltage
Voltage by which an installation or part of it is designated.

Short circuit
An abnormal situation characterised by a low impedance accidental connection between parts of the electric installations normally under different voltage or between a part under voltage and the ground.

Fault current
Maximum current passed through the OCL under fault conditions within a defined short time period, between live equipment and earth.

Stray current
Portion of the return current which, over at least part of its travel, follows paths other than the return circuit (for example water pipes or telephone cables).

Feeding point
Point at which the feeding system supply is connected to the contact line.

Isolation
Disconnection of a section of OCL from the source of electrical energy, either in an emergency or to facilitate maintenance.

Sectioning
The division of the contact line into electrical sections, each of which may be isolated from the adjacent sections e.g. by means of a switch.

Longitudinal sectioning
Electrical division of the contact line of the same track.

Lateral sectioning
Electrical division of the contact line of the adjacent tracks.

Sectioning point
An arrangement of the contact line equipment to provide insulation between adjacent sections of the contact line while allowing continuous current collection.

Electrification clearance gauge
Contour which contains the various live parts of an OCL, allowance being made for static electrical clearances, and from which all other fixed objects must be kept clear.

Electrical clearance (insulation distance of contact line)
Minimum distance permitted between a fixed structure and parts energised at contact line voltage.

Safety distance
The distance separating the zone around live conductors which workers must never enter during work nor reach into with arms, body parts or tools.

2.4 - Mechanical and geometrical

Span
The OCL from one support or suspension point to the next.

Tension length (mechanical section)
Length of OCL between two anchoring points.

Anchoring point
The point where the conductors of the OCL are fixed to the support directly or by means of tensioning devices.

Mid-point anchor
The anchoring equipment near the middle of the mechanical section, which prevents the OCL from making longitudinal movements.

Overlap span
An arrangement of adjacent mechanical sections of the OCL providing continuous contact of the pantograph with the contact wire(s) and continuous current collection.

Stagger
Displacement of the contact wire(s) to opposite sides of the track centre at successive supports to avoid localised wear on the pantograph strips.

System height (encumbrance)
Vertical distance from the lower face of the grooved contact wire to the middle of the catenary, measured at the support.

Gauge
Cross-sectional dimensions defining the maximum permitted dimensions of vehicles or the minimum dimensions of fixed structures.

Mechanical clearance
Minimum distance permitted between fixed structure (including OCL) and mechanical moving parts of trains (i.e. pantograph).

Height
Distance from the top of the rail to the lower face of the contact wire, measured perpendicular to the track.

Minimum height
Minimum value of the contact wire height in the span in order to avoid the arcing between one or more contact wires and vehicles under all conditions.

Gradient
Ratio of the difference in height of the OCL above the rail level at two successive supports to the length of the span.

Contact wire uplift
Vertical upward movement of the grooved contact wire due to the force produced from the pantograph.

Lateral resilience (lateral elasticity)
The displacement of the contact wire horizontally in the across-track direction per unit of applied force.

Hard spot
Point in the OCL in the region of the registration arm, which has a low vertical resilience.

Catenary sag
Difference in height between the support points of the catenary and its lowest point.

Contact wire sag
Difference in height of the contact wire under support points and in the middle of the span.

Contact wire pre-sag
The initial value of sag deliberately given to the contact wire during installation.

Neutral temperature
Reference temperature for calculating the mechanical tensions in setting up fixed conductors.

2.5 - Functional

Insulated overlap
Sectioning point formed by overlapping the ends of adjacent sections of contact line, allowing parallel running, insulation being provided by a suitable air gap between the two sets of equipment.

Neutral section
Section of the contact line provided with a sectioning point at each end to prevent successive electrical sections differing in voltage or phase being connected together by the passage of the current collectors.

Overhead crossing
Arrangement employed where contact wires cross at an angle, permitting the current collector to travel along either of the wires.

OCL over level crossing
Span of OCL over a level crossing of a railway line with a road.

2.6 - Supports

Support structure
Parts which support the conductors and the associated insulators of an OCL.

Mast (pole)
A main vertical support construction with one end embedded in the ground adjacent to the track, either directly or through a separate base or foundation to provide for support, tensioning and registration of the OCL.

Portal structure
Support consisting of a transverse beam and masts situated on either side of the tracks.

Headspan suspension
A portal arrangement in which the beam is replaced by an arrangement of cross-span wires.

Cross span (span wire)
Wire or cable, normally electrically insulated, placed across the track and used either to support one or more OCL (headspan), or to carry lateral registration force (cross-span registration).

Rigid support
A method of attaching an OCL rigidly to its support.

Flexible support
A method of attaching an OCL to its support by means of one or more intermediate transverse wires or other flexible devices.

Cantilever
Support consisting of one or more transverse members projecting from a mast.

Hinged cantilever
Cantilever fixed to the mast in such a way as to allow movement of the OCL longitudinally and, to a limited extent, vertically.

Stay (tie, guy)
Rod, wire or cable, with a tensioner, to anchor a mast or a cantilever.

Pull-off
Device used on curves or at track turnouts to keep conductors in their correct position.

Foundation
Construction, usually of concrete or steel, completely or partly buried in the ground on which the support is mounted. The foundation must provide stability to all loads borne by the support.

2.7 - Components

Disconnector
A mechanical switching device which, in the open position, provides an isolating distance in accordance with a specified requirement. A disconnector is capable of opening and closing a circuit only when negligible current is cut out or brought in.

Section insulator
Sectioning point formed by insulators inserted in a continuous run of a contact line with skids or similar devices to maintain continuous current collection.

Suspension insulator
Component of a string of insulators capable of being loaded in tension.

Suspension clamps
Fitting providing mechanical connection between the catenary or contact wire and the supporting assembly.

Dropper
Component used to suspend a cross-span registration, an auxiliary catenary or a contact wire from a headspan or a longitudinal catenary.

Connector (distance clamps)
Fitting providing mechanical connection (and fixed distance) between two electrical conductors.

Contact wire splice
Fitting for joining two lengths of contact wire mechanically and electrically.

Registration arm
Stiff component, electrically insulated from its support, carrying the steady arm and often hinged to allow along-track or vertical movement.

Steady arm
Hinged arm used to hold the contact wire in its correct across-track position and normally fixed to the registration arm so that the steady arm is always loaded in tension.

Tensioning device
Arrangement enabling the mechanical tension of conductors to be adjusted.

Automatic tensioning device
Device used in tensioning equipment to maintain automatically constant mechanical tension in conductors within certain temperature limits.

Balance weight tensioner
Automatic tensioner attached to a mast to ensure constant tension in conductors by means of balance weights.

Spring tensioner
Automatic tensioner attached to a mast to ensure constant tension in conductors or in cross-span registration cables by means of springs.

Terminal fitting
Fitting attached to the end of a wire or cable in order to anchor it.

2.8 - Return and earth circuits

Return circuit
The electric circuit comprising the running rails or a return current rail, their electrical connections and the return cables to the sub-station.

Track return system
System in which the running rails of the track form a part of the return circuit for the traction current.

Insulated return system
System in which the conductors forming the return circuit are insulated from the track.

Return conductor
Any part of the return circuit.

Return cable
Insulated return conductor forming part of the return circuit and connecting the rest of the return circuit of the sub-station.

Rail joint bond
Conductor ensuring the electrical continuity of rails at a joint.

Welded bond
Electrical connection the two ends of which are welded to the ends of the rails at a joint.

Insulated rail joint
Mechanical rail joint which separates the rails electrically.

Impedance coil
Coil mounted in the track circuit to separate the paths for traction current flow from the signalling current.

Booster transformer
Transformer with a ratio of unity having one of its windings connected in series with the contact line and the other in series with an insulated return conductor.

Earth wire
Metal wire connecting supports to earth or to rail to protect people and installations in the event of an insulation fault and which may also be used as a return cable.

Lightning protection cable (safety wire)
Earthed metal wire fitted above the OCL to protect it against lightning.

Earth fault relay
Relay which operates when a failure of insulation to earth is detected in protected equipment or circuits.

Spark gap
Device used to connect a circuit to earth in the event of a fault in live circuits.

Earthing device
Device used to connect a circuit to earth.

Earthing reactor
Reactor inserted in the equipment earth circuit before its connection to the mass of a vehicle, encouraging return current to flow through the earth brushes but preventing the vehicle from being made live in the event of an interruption in the earth-brush circuit.

Lightning arrester
Device intended to protect the electrical apparatus from high transient overvoltages and to limit the duration and amplitude of the follow-on current.

2.9 - Maintenance

Elementary maintenance activity
Unit of work into which a maintenance activity may be broken down at a given indenture level.

Maintenance
Combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Supervision (monitoring)
Activity performed either manually or automatically, intended to observe the state of an item.

Maintenance interventions
Combination of all technical actions (excluding administrative and supervision actions) intended to retain an item in, or restore it to, a state in which it can perform a required function.

Inspections
Activities intended to monitor the state of the OCL and to evaluate the extent of maintenance work required, such as foot inspections, test car runs, observation of pantograph reaction etc. The inspections are usually undertaken with the OCL switched on.

Measurements
Activities carried out to measure the main parameters (geometrical, mechanical and electrical), which characterise the condition and the reliability state of the OCL system. Measurements may require track possession and the electrical line to be switched off.

Measurement runs
Activities intended to provide evidence of the static as well as dynamic behaviour of the OCL system. The dynamic behaviour is generally determinate at the maximum permissible line speed. Measurement runs are usually made with the OCL live.

Examinations
Activities undertaken to check those parts of the installations which can be inspected thoroughly only with the OCL switched off and earthed. They are arranged for specific areas, when required, as a result of inspections, measurement runs, short circuits and disruptions. Generally there is no prescribed frequency. Examinations may also be made on a spot check basis.

Preventive maintenance
Maintenance activities carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item.

Scheduled maintenance (hard time maintenance)
Preventive maintenance carried out in accordance with an established time schedule.

Unscheduled maintenance (on condition maintenance)
Maintenance activities carried out, not in accordance with an established time schedule, but after receipt of an indication regarding the state of an item (inspections, measurements, etc).

Corrective maintenance
Maintenance activities carried out after fault recognition and intended to put an item into a state in which it can perform a required function.

Fault diagnosis
Actions taken for fault recognition, fault localisation and cause identification.

Fault recognition
The event of a fault being recognised.

Fault localisation
Actions taken to identify the fault sub-item or sub-items at the appropriate indenture level.

Fault correction
Actions taken after fault localisation to restore the ability of the faulty item to perform a required function.

Fault repair
The part of corrective maintenance in which manual actions are performed on the item (manual activity to repair faults).

Fault correction time
That part of active corrective maintenance time during which fault correction is performed.

Fault localisation time
That part of active corrective maintenance time during which fault localisation is performed.

Repair time
That part of active corrective maintenance time during which repair actions are performed on an item.

Deferred maintenance
Corrective maintenance which is not immediately initiated after a fault recognition but is delayed in accordance with given maintenance rules.

Extraordinary maintenance
Interventions planned to re-establish the reliability of installations, recovering long periods of poor or non-existent routine maintenance.

Renewals
Interventions planned to improve the performance of operating installations through large-scale works, such as renewal of components, adjustments of particular functional aspects and/or improvements of operating characteristics.

Maintainability
The ability of an item under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources.

Reliability
The ability of an item to perform a required function under given conditions for a given time interval.

Availability
The ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided.

Track possession
Availability of the track for works.

Track possession duration
Length of time of the track possession.

Timetable for maintenance
Suspension of traffic on the tracks for maintenance.

3 - Groups of OCL parts and components

OCL are divided into groups (or families) of components or parts, functionally connected to each other, and for which a uniform plan for maintenance work can be drawn up.

Appendix A - page 56 shows the relevant diagrams and drawings of the main OCL parts or components dealt with in this leaflet.

3.1 - Supports

The "supports" group of components is composed of the structures supporting OCL and earthed (see point A.1 - page 57), namely:

- masts,
- portals,
- headspan suspensions,
- suffix posts for tunnel cantilevers,
- cantilevers,
- stays,
- foundations,
- other parts connected to the support and earthed (excluding return and earth circuits).

3.2 - Suspensions

This group contains all the parts installed between supports and conductors (including insulators), as shown in point A.2 - page 58, namely:

- supporting and registering elements,
- suspension clamps,
- hinged cantilevers,
- insulated cantilevers,
- tie bars,
- pull-offs,
- registration arms,
- suspension insulators.

3.3 - Spans

The family of "spans" includes conductors and the other live elements between two consecutive supports (see point A.3 - page 59), namely:

- catenaries,
- contact wires,
- contact wire splices,
- connectors,
- stitch wires,
- links between catenaries and wires,
- droppers and other elements,
- feeders,
- clearances (mechanical and electrical),
- gauge (obstacles).

3.4 - Particular spans

This family consists of special spans (see point A.4 - page 60), requiring more maintenance by comparison with ordinary spans, for example spans formed by several conductors in parallel or crossing over each other, spans approaching tensioning points, spans over level crossings, etc.:

- overlap spans,
- overhead crossings,
- neutral sections,
- OCL over level crossings,
- section insulators,
- sectioning points.

3.5 - Anchors and tensioning devices

This group includes all the elements normally used to maintain the OCL conductors in mechanical tension (see point A.5 - page 61), namely:

- terminal fittings,
- automatic tensioning devices,
- mid-point anchors,
- spring tensioners,
- balance weight tensioners.

3.6 - Sectioning and feeding points

This family includes all equipment mounted on supports to switch or protect the OCL or on the OCL for detection purposes (see point A.6 - page 62), such as:

- disconnectors, switches and other apparatus,
- automatic/handler devices,
- electrical connections between disconnectors and conductors.

3.7 - Return circuits

This group is composed of the elements forming the intended path for the traction return current (see point A.7 - page 63), namely:

- connections between ground and return circuit,
- elements of electrical continuity for the rails,
- links to the impedance bond for return current,
- return conductors.

3.8 - Earthing and protection circuits

This family contains the conductors and the connected elements and devices adopted to protect people from accidental energising of the structures (see point A.8 - page 64), namely:

- ground wires,
- connections between supports and ground or rail,
- voltage limiters, diodes,
- lightning arresters,
- grounding rods.

3.9 - Others

This group encompasses all the remaining parts, components and elements of the OCL or auxiliary required for safe operation, namely:

- transformers (auxiliary – measurement),
- warning signals,
- signs,
- shields.

4 - Maintenance activities

Maintenance is the combination of all technical and administrative action including supervision action, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Administrative action involves the organisation and management of the necessary resources, such as personnel and maintenance vehicles/equipment, and is subject to the influence of policy strategies.

Supervision action is designed to observe the condition of the main OCL components and to improve the diagnosis of how well they are operating over time.

The combination of all technical action intended to put every item in a state in which it can perform a required function, is done through maintenance work which is divided functionally into two different ways of intervening, depending on the acceptable probability of fault occurrence defined (preventive and/or corrective maintenance).

Preventive maintenance involves supervision of the condition of the catenary to evaluate the extent of maintenance work required and is carried out at predetermined intervals or according to prescribed criteria with the aim of reducing the probability of failure or deterioration of the functioning of an item.

Corrective maintenance is always carried out after a fault has been recognised and is intended to put an item in a state in which it can perform a required function.

Both of the above types of maintenance interventions are necessary, but the choice of the mix to adopt and of the quantity and quality of the corresponding resources to employ depends on the maintenance levels targeted and the costs to be sustained.

Preventive maintenance is based on inspections, observations, checks and measurements, examinations, scheduled maintenance and unscheduled maintenance. Scheduled maintenance is carried out in accordance with an established time schedule (hard time maintenance), while unscheduled maintenance occurs after obtaining an indication regarding the condition of an item (on-condition maintenance).

Hard time and on-condition maintenance are not always an alternative and the decision to opt for one or the other depends on a cost analysis. The current trend, with the most used OCL components is to pass from hard time maintenance (scheduled maintenance is perhaps more costly) to on-condition maintenance. Corrective maintenance can exist without preventive maintenance, but the reverse is not true because the occurrence of faults due to a material’s defects, human errors or for external reasons will never be eliminated.

It is important to note that fault correction (the action to restore the ability of the faulty item to perform a required function) includes manual fault repair and action to recognise and localise the fault.

The term "deferred maintenance" is sometimes used for corrective maintenance which is not immediately initiated after a fault recognition but is delayed in accordance with given rules. Deferred work is often preceded by examinations and measurements, hence it becomes work planned to restore the reliability of installations and recover from long periods of poor or non-existent routine maintenance, in other words, extraordinary maintenance interventions.

Extraordinary maintenance is carried out mainly for corrective purposes, but in the case of deferred or planned maintenance work, it completes the maintenance cycle and hence it is also preventive maintenance.

Last but not least, renewals are interventions planned to improve operating installations' performances through substantial maintenance work, such as renewal of components, adjustments of particular functional aspects and/or improvements of operating characteristics.

The frequency and intensity of maintenance work depend on the following main criteria:

- importance of the line,
- maximum line speed,
- number of train (or pantograph) journeys per day,
- type of traffic related to the current intake and to the pantograph strip materials and design,
- type of system and characteristics of the OCL,
- condition and age of the OCL,
- type and extent of air pollution,
- magnitude and duration of short-circuit currents,
- number of operating disturbances.

The OCL is kept in good condition and reliable through a number of elementary operations which may belong to seven different categories of activities (macro-activities):

- inspections, observation, surveillance,
- verifications, checks, measurements,
- scheduled maintenance interventions (hard time),
- on-condition maintenance interventions,
- fault repair interventions,
- extraordinary maintenance interventions,
- renewals.

The first three macro-activities (inspections, measurements and scheduled maintenance) characterise preventive maintenance, while the next two (on-condition maintenance and fault repair) are typical of corrective maintenance, and also take account of the results of the first two macro-activities.

All operations to be carried out must be considered not as a consequence of unjustified events, but as the result of management or maintenance strategies be they by obligation or by choice.

4.1 - Inspections and observation

This group of activities consists of simply observing the condition of installations without disrupting train traffic and with the OCL remaining live.

This work is normally performed by experts who observe the condition of the OCL from foot paths alongside the railway line.

The inspections are carried out on foot by carefully observing the OCL structures and components. Along tracks without side paths, on bridges or inside tunnels, the observation can be done by trolley at very low speed.

Special inspections to observe particular situations can be carried out by trolley at different speeds, on normal trains and/or by special means.

During the inspections, simple measurements may be made, such as:

- the distance between masts and the nearest rail,

- the position of the counterweights in relation to the outside temperature.

In addition to noting the condition of OCL, it is important to observe also the presence of trees, bushes, icicles and other objects that interfere with electric train operations and might even cause serious accidents, hence inspections and observations must attach importance to the clearance gauge, the space required for the passage of the pantograph and the safety clearances required by the OCL.

4.1.1 - Foot inspections

During foot inspection, all parts of the OCL are observed for their operational reliability without inspectors actually climbing the masts. General attention must be paid to the soundness and work position of structures, components and elements relevant to the groups mentioned in point 3 - page 14, with account being taken of the dynamic behaviour of parts under the occasional passing of trains.

Obviously whenever a train passes by, the reaction of the OCL under the forces exerted by the movement of the pantographs should be observed with special attention in order to assess the subsequent uplift of the contact wires and the dynamic geometrical positions of the conductors.

More systematically, in absence of passing trains, the overview of any support structure should include above all the observation of:

- condition of the structure (masts, portals, etc.),

- condition of foundations and concrete masts (damage, especially cracks),

- inclination and straightness of the masts,

- distances between masts and the nearest rail,

- readability of mast numbers (markers),

- loose anchors and stays,

- absence of refuse and plant growth in the ballast,
- broken strands in headspan and cross-span suspension cables,
- earth movements.

In observation of suspensions, it is important to pay attention especially to:

- the condition of structural elements placed between supports and conductors or other live parts,
- the inclination of steady and registration arms and of associated strut tubes,
- the position of cantilevers in relation to outside temperature and the distance from reference points,
- broken strands in pull-offs,
- the position and condition (cleanliness, cracks, etc.) of insulators.

When inspectors walk alongside spans, it is important that they carefully check:

- the proper position of the crossing bars and the alternating link wires in relation to the temperature,
- loose or damaged droppers and auxiliary wires,
- kinking and twisting of the contact wires,
- broken strands in catenaries and other cables,
- slack in fixed anchor cables, wires and catenary system elements,
- sparking when a pantograph passes by.

Special attention is required also on particular spans, to observe:

- the position of crossing and converging wires relevant to outside temperature,
- the condition and position of section insulators and phase separators,
- the smooth movement of the pantograph through sectioning insulators and OCL crossings,
- electrical clearances in insulated overlap spans.

Regarding the anchors of conductors and the tensioning devices, it is very important to observe carefully:

- the position of the insulators,
- the cable run-in of the weight tensioning equipment,
- the flexibility of the tensioning equipment (lifting of the weights),
- the position of weights in relation to the temperature.

If hydraulic tensioning equipment is used, attention must be paid to the:

- oil level,
- oil pressure,
- absence of leaks,
- time limits for container pressure tests.

Inspectors must stop at sectioning and feeding points where it is important to note:

- hot and overheated cables in electric connections,
- chipped or damaged screens,
- traces of flash-over,
- dirt accumulation,
- leakage and lack of insulation on the terminations of high voltage cables,
- condition of circuit breakers and horn type switches, including functioning of manual and local control.

Concerning return circuits and earthing or protection circuits, maximum attention must be paid to the:

- state of connections to rails, masts, etc.,
- condition of conductors,
- effectiveness of corrosion protection,
- integrity and condition of valves, diodes, circuit breakers and other devices,
- oil level of suction transformers,
- state of the earthing devices and voltage detectors located along the line.

Lastly, inspectors must observe the remaining OCL components, auxiliary equipment and other aspects which can affect traffic safety or human safety, such as:

- adequate safety clearances between live and earthed parts,
- presence of trees and bushes, as well as keeping the gauge clear for the pantograph run,
- state of protective screens and warning signs,
- position and state of the signals for electric train operation,
- proper operation of the means for voice communication with sub-stations or electrical control command centres.

All the abnormal situations detected and the measures taken should be reported on special forms by the personnel employed in inspections in order to provide maximum visibility about the real conditions of the OCL and to enable the necessary interventions to be planned as soon as possible or delayed.

The period of time between two complete subsequent inspections is usually recommended by the different IMs. It depends on the OCL characteristics, line speed and the performances expected as well as on the maintenance level chosen (see point 5.5 - page 31).

Generally, observation work is scheduled as a mix of inspection on foot, inspection by trolley and on trains, trying to improve productivity without lessening the effectiveness of the data collected and of the details about the real condition of the OCL.

Furthermore, in the future the results of these activities will be examined more and more closely and compared with data output from fault diagnosis and monitoring systems which are being introduced and expanded increasingly.

Appendix D - page 77 contains a number of tables showing the frequency adopted by various IMs for maintenance activities starting with inspections and observation.

Partial or rapid inspections may be suggested between subsequent inspections on foot.

Ad hoc inspections should be made to look at specific components or observe certain parts of a line depending on specific concerns or contingent aims.

4.1.2 - Inspections by trolley

Instead of on foot inspections or alternating with them, especially where there is no trackside path or when time is short and resources are scarce, it may be useful to observe the OCL condition from inside a trolley running at very low speed and stopping often alongside masts, portals, special spans, etc.

These inspections are particularly effective to ascertain the sound condition of conductors, suspensions and cantilevers inside tunnels, illuminating them from the roof of the trolley.

4.1.3 - Inspections by train

These inspections are particularly recommended to observe the dynamic behaviour of the OCL caused by the pantographs of the train in which the observer is travelling. It is generally easy to view the OCL from the first coach near the locomotive in suitable trains. From this vantage point, special attention must be paid to observation of the pantograph reaction, estimating contact wire height and stagger and, in particular, also:

- contact wire lead-ins and exits at tensioning points, section insulators, switches and crossings,
- gauge clearance for the pantograph,
- arcing at the pantograph run.

4.2 - Verifications, checks, measurements

This group of activities includes periodical work done to check or monitor physical or functional characteristics of equipment or components.

Among this type of operations, it may be important to separate those required by law from the remaining ones which are not, so as to identify the relevant costs of operations which are mandatory by law and those which are decided by IMs.

Some examples of measurements required by law are:

- verifications of the effectiveness of earth circuits for human safety,
- verifications of the distances between live parts of the OCL and the earth,
- verifications (mechanical and/or electrical) of some of the equipment and devices used by maintenance workers from the standpoint of human safety.

Among the periodical OCL verifications recommended, it is mainly important to measure the following generally under suspensions and in the middle of spans:

- height of contact wires and catenaries,
- stagger of contact wires and catenaries,
- wear of contact wires.

Another important test consists of striking insulators (made of porcelain or glass) in order to ascertain their integrity.

Measurement of geometrical parameters (height, stagger and wear) is generally requested once per year, but it is suggested that height and stagger on the most important lines be measured both in winter and in summer to better assess the effect of outside temperature on the layout of the OCL.

Wear measurements may be more frequent depending on traffic on a line, the state of the line and the characteristics of the pantograph strips.

Until several years ago, measurements were carried out manually using special equipment or from the platforms of ladder trolleys, but today checks are increasingly carried out automatically using state-of-the-art systems installed in special trolleys, coaches or trains, and which provide continuous data on the checks made as well as easy calculation of other parameters such as gradient, sag, etc.

The tables in Appendix D - page 77 also indicate the frequencies recommended by the IMs for these activities depending on the maintenance level chosen (see point 5.5 - page 31) and the other aims pursued.

4.2.1 - Recording runs

Recording runs are normally executed with the OCL live and are intended to provide evidence of the static as well as the dynamic behaviour of the catenary system. In the latter case, they are conducted to ascertain that the OCL functions correctly under moving pantographs and the runs must be executed with an equipped train or car at the maximum line speed.

The first parameters checked automatically are the height and the stagger of the contact wires, but many other geometrical, mechanical and electrical parameters may be measured with new technologies, such as contact wire wear, the contact forces exerted by the moving pantograph, the OCL voltage, etc.

The software of these systems is being enhanced continuously and can also be used to calculate many other parameters; tools can be used to represent the static and/or dynamic characteristics and behaviour of the OCL.

4.2.2 - Examinations

Examinations involve those parts of the installations which can be inspected only with the power supply switched off and the catenary earthed. Examination and measurements are organised for specific route sections. Generally they are not executed at a specific date but as a result of inspections, recording runs, short circuits and disruptions.

Examinations essentially cover the following points:

- verification of the effectiveness of contact wire crossings and lead-ins with a pantograph contact force equalling the average dynamic contact force in normal operation,

- the condition of clamps,

- loose contact between crossing cables and wires,

- functioning of cable pulleys,

- the condition of section insulators and phase separators, including their height and the position of their copper runners,

- the condition of insulators (chipped or damaged screens, traces of flashover, dirt accumulation),

- the condition of circuit breakers and horn type switches, with particular reference to the cleanliness of contacts (scorching and dirt), adjustment or replacement of arcing horns, connectors and clamps, moving parts,

- the condition of suction transformers and their components (lead-ins, connections, oil level, etc.).

4.3 - Scheduled maintenance (hard time)

Systematic maintenance includes all the operations that must be carried out at specific times to ensure that the OCL remains as reliable as when new and to maintain the OCL in efficient condition. This maintenance work must guarantee that the installations are managed at efficient technical levels, as well as their continuity and safe operation as when they were new.

During these interventions, all manual activities must be concentrated together in order to limit the need for track possessions and optimise the resources used in the work, the aim of which is to:

- eliminate and/or correct all abnormal situations detected as a consequence of inspections, observation, recording runs, etc.,
- replace insulators or other damaged or broken components detected during inspections,
- check or measure all that cannot be done with the OCL live,
- inspect with maximum care all that could not be seen during on foot inspections,
- examine carefully the integrity of conductors,
- verify the work position of the various elements and correct it,
- check for loose clamps and restore them,
- detect other damaged or broken components and restore or replace them.

These activities include all the verifications and examinations done manually.

The period of time between two complete cycles of systematic maintenance usually recommended by the different IMs depends on the OCL characteristics, the line speed and the performances expected, as well as on the maintenance level chosen (see point 5.5 - page 31).

The tables in Appendix D - page 77 also include the frequencies for this type of activities as recommended by IMs.

In the future, it is expected that these activities will be carried out on a smaller scale and data obtained from observation will be compared increasingly with output from the growing number of fault diagnosis and monitoring systems.

Partial or rapid interventions may be suggested between successive complete cycles of maintenance.

Ad hoc examinations as mentioned in point 4.2.2 - page 25 may be carried out to restore specific components or to increase maintenance on precise sections of line, depending on specific concerns or contingent aims.

4.4 - On-condition maintenance

On-condition maintenance involves all the operations planned on the basis of the results of inspections, observation, recording runs and surveillance, to eliminate abnormal situations jeopardising the integrity and reliability of the installations and to restore the condition of the OCL in accordance with the performances expected.

4.5 - Fault repair

Fault repair refers to the work of repairing and restoring installations after damage has occurred; it involves fault diagnosis, repair and subsequent checks to ascertain proper functioning or combinations of these.

Above all, the event of a fault must be detected and localised in order to identify the faulty item (with its appropriate site and degree of failure) and to organise and carry out the corrective action needed to restore the component so that it can perform the required function. After restoring the OCL, it is extremely important to analyse factual evidence to define the causes which could have produced or facilitated the fault occurrence.

4.6 - Extraordinary maintenance

Maintenance activities can ensure a life cycle of about 30 to 40 years for OCL equipment until total or partial renewal is necessary.

In fact, if routine maintenance is poor or non-existent, it is often necessary to plan and carry out extraordinary maintenance work requiring a large number of resources and to include operations considered necessary to be done ad hoc in order to restore the initial conditions of operation and to re-establish the reliability of the installations, such as:

- complete reset of the entire OCL from time to time,

- complete substitution of some components of the same type as the previous ones,

- special work to restore OCL performance without making enhancements.

4.7 - Renewals

Renewals are operations carried out to improve the performance of the installations concretely, through substantial systematic works such as:

- complete replacement of components with others offering better characteristics in order to increase the life cycle of the installations,

- adjustment of particular functional aspects and/or improvements of some operating parameters with the aim of increasing the reliability of the OCL or to improve the performances required on the relevant railway line.

Particular care must be given to make a distinction between extraordinary maintenance work, such as changing of conductors or installation of new masts (of the same type as the previous ones), and renewal work, such as replacing devices or components with new ones of more recent technology or new functions, pending complete replacement of the entire installation.

5 - OCL classification for maintenance purposes

It is important to take account of line performance in order to plan maintenance activities. In fact, the frequency of maintenance interventions, the volume of work done and the strategy adopted for maintenance planning and management may vary depending not only on the OCL characteristics but also on the performance required for a railway line.

First of all, the main parameters influencing performance must be considered, namely:

- the line speed compared with the speed designed for the OCL installed;
- traffic density determined by the number of electric trains run per day or by the number of pantographs touching the contact line.

5.1 - OCL main characteristics

The main characteristics considered are those more directly connected with the quality of current collection and of the interaction between the pantograph and the catenary, for instance:

- the weight of the OCL, which is higher for the DC lines by comparison with AC lines;
- the amplitude of the current absorbed by pantograph which is lower in AC than in DC lines;
- the absence of or adoption of automatic tensioning for contact wires and/or for catenaries.

In particular, the design characteristics of the OCL may limit the speed worked on a line depending on whether the system is AC or DC.

5.2 - Line speed

The maximum speed of a line is generally fixed by the track characteristics (such as gradient and curve radius), the presence of level crossings, the performance of the signalling installations, etc.

The OCL characteristics may limit the line speed depending on the above-mentioned tensioning of the conductors at v_2 (without any tensioning of the conductors) or v_3 (with wire tensioning and the fixed termination catenaries).

In practice, it may be important to consider the function of the track served by the OCL and the different velocities of the pantograph as it runs along the catenary. Consequently it might be useful to consider the above limits for the low and medium speed of the lines and considering also situations of very low speed (v_1) on secondary lines and in stations or on stabling tracks, as well as high speed up to v_4 (maximum speed for conventional lines with all the conductors obviously automatically tensioned) and very high speed (up to v_5) on high speed lines. Lastly, it may be advisable to consider five levels of line speeds, characterised as follows:

- v_1 = very low speed, generally admitted on secondary tracks (stations, stabling tracks, etc.) where the OCL characteristics are also very poor (e.g. few conductors with small sections and without automatic tensioning). This speed, depending on various situations and many other criteria, may be, for example, up to 60 km/h;

- v_2 = low speed, generally admitted on secondary lines (high radius curves or steep gradients, without technologies installed, etc.) and on the secondary tracks of stations requiring better performances than the category above, e.g. where all the conductors of the OCL are not automatically tensioned. In these cases, the maximum speed can be up to 120 km/h;

- v_3 = medium speed, generally admitted on running tracks of conventional lines (medium radius curves, a large number of level crossings or not equipped with track circuits for signalling, etc.), e.g. where the OCL contact wires are automatically tensioned and the catenaries with fixed terminations. The relevant speed, in these cases, shall not exceed 160 km/h;

- v_4 = high speed, generally admitted on the main conventional lines (straight lines, without level crossings, etc.), e.g. where all the OCL conductors are automatically tensioned, with the standards of upgraded lines and enhanced performance. The speed in this case may be up to 220 km/h;

- v_5 = very high speed, generally adopted on high-speed lines, e.g. where the standard of the OCL is particularly sophisticated to permit a maximum train speed up to 350 km/h.

5.3 - Traffic density

Traffic density can be measured for the purpose of ascertaining OCL performance by the number of electric trains worked on any track per day. More precisely, it is preferable to refer to the number of pantographs passing on the line per track and per day, considering also the pan strip characteristics and the material used. In summary, traffic density can be considered:

- very low when a track is worked by no more than n_1 trains per day and the relevant OCL is worked by no more than p_1 equivalent pantographs per day;

- low when a track is worked by no more than n_2 trains per day and the relevant OCL is worked by no more than p_2 equivalent pantographs per day;

- medium when the track is worked by no more than n_3 trains per day and the relevant OCL is worked by no more than p_3 pantographs per day;

- high when the track is worked by no more than n_4 trains per day and the relevant OCL is worked by more than p_4 equivalent pantographs per day;

- very high when the track is worked by up to n_5 trains per day and the relevant OCL is worked by up to p_5 equivalent pantographs per day;

Very low traffic densities (n_1 and p_1) or very high densities (n_5 and p_5) can be considered in relation to the importance of the line.

Equivalent pantograph

To take account of the pan strip design and materials used, which cause more or less contact wire wear, it is important that the characteristics of each pantograph are compared with those of a reference pantograph which is different for DC and AC systems depending above all on the intensities of current collection.

The DC equivalent pantograph is defined as a conventional pantograph equipped with carbon strips. The use of pan strips made of other materials such as copper may increase contact wire wear substantially. Consequently, each pantograph may be equal to k equivalent pantographs depending on the wear produced, with k equal to 5 in the case of copper.

The AC equivalent pantograph is represented by a conventional pantograph equipped with graphite strips. If strips made of other materials are used, the contact wire wear may vary. Consequently, each pantograph may be equal to k equivalent pantographs depending on the wear produced with the same runs. However it should be noted that in AC systems, the problem may be less important due the low current collection.

Based on experience acquired, the different IMs may define the values to apply for coefficient k depending also on the intensities of the current intake.

5.4 - Line categories for maintenance levels

Tracks and railway lines can be classified in different categories, characterised by the maintenance level required for the relevant OCL, to take account firstly of the line speed, the traffic density and then the other important aspects, both operational (depending on the commercial or strategic use of the relevant tracks) or technical (depending on the real characteristics of the relevant OCL) or environmental (depending on climatic conditions, pollution, etc.). In particular it is important to consider the following elements:

- importance of the line,
- number of operating disturbances,
- number of faults permitted for the OCL,
- type OCL system and characteristics,
- greater or lesser use of the lines compared with the projected performance of the OCL,
- type of traffic in relation to the current intake and to the pantograph strip materials and design,
- condition and age of the OCL,
- magnitude and duration of short-circuit currents,
- type and extent of air pollution.

Different examples of line categories depending on these aims are shown in Table 1, to enable IMs to classify their lines and tracks on the basis of these guidelines.

Table 1 : Line categories

Equivalent pantographs per day [p]	**Maximum line or track speed [km/h]**				
	$\leq v_1$	$\leq v_2$	$\leq v_3$	$\leq v_4$	$\leq v_5$
$\leq p_1$	e.g. Secondary tracks, very low traffic, OCL fixed	e.g. Secondary lines, very low traffic, OCL fixed	e.g. lines of minor importance, very low traffic, OCL semi-tensioned		
$\leq p_2$	e.g. Secondary tracks, low traffic, OCL fixed	e.g. Secondary lines, low traffic, OCL fixed	e.g. lines of minor importance, low traffic, OCL semi-tensioned		
$\leq p_3$		e.g. Secondary lines, medium traffic, OCL fixed	e.g. Main lines, medium traffic, OCL semi-tensioned	e.g. Upgraded lines, medium traffic, OCL fully tensioned	
$\leq p_4$			e.g. Main lines, high traffic, OCL semi-tensioned	e.g. Upgraded lines, high traffic, OCL fully tensioned	e.g. High speed lines, high traffic, special OCL
$\leq p_5$			e.g. Main lines, very high traffic, OCL semi-tensioned	e.g. Upgraded lines, very high traffic, OCL fully tensioned	e.g. High speed lines, very high traffic, special OCL

Appendix B - page 66 contains descriptions of the main characteristics of the OCLs adopted by European IMs in relation to the maximum line speed and traffic density.

5.5 - OCL maintenance levels

The frequency of inspections and of other maintenance interventions, as well as the type, degree and quality of the work done, may be defined referring to the maintenance level required, line-by-line and track-by-track.

Hence the quantity and the quality of maintenance activities may vary from the minimum for the OCL on technologically poor secondary tracks worked by few trains at very low speed to the maximum for the OCL on technologically advanced mainline tracks worked by a large number of trains at high or very high speed.

IMs should choose and define the maintenance levels for each line or track after having better identified their line categories on the basis of the examples given in Table 1.

On this basis, the lines or the tracks involved can be divided into five main categories, corresponding to the relevant maintenance levels, increasing from level A to level E, as shown in Table 2.

Table 2 : OCL maintenance levels

Equivalent pantographs per day [p]	**Maximum line or track speed [km/h]**				
	$\leq v_1$	$\leq v_2$	$\leq v_3$	$\leq v_4$	$\leq v_5$
$\leq p_1$	**A**	**A**	**B**		
$\leq p_2$	**A**	**B**	**B**		
$\leq p_3$		**B**	**C**	**D**	
$\leq p_4$			**C**	**D**	**E**
$\leq p_5$			**D**	**D**	**E**

The values generally adopted for the maximum speed in the 5 columns and in the 5 rows of the tables may vary, for example, within the following speed ranges:

- v_1 = 60 ÷ 90 km/h; v_2 = 100 ÷ 120 km/h; v_3 = 140 ÷ 160 km/h; v_4 = 200 ÷ 220 km/h; v_5 = 250 ÷ 280 km/h for DC systems and 300 ÷ 350 km/h for AC systems;
- p_1 = 20 ÷ 30; p_2 = 40 ÷ 60; p_3 = 80 ÷ 120; p_4 = 140 ÷ 160; p_5 = 250 ÷ 300 equivalent pantographs per day and per track.

As already mentioned in point 4 - page 18, Appendix D - page 77 contains tables completed by the different IMs with the frequencies adopted for scheduled maintenance activities depending on the maintenance level chosen and all other aims pursued.

6 - OCL information data base

The parts, components and elements of the OCL installations (see point 3 - page 14) that need to be taken into account for maintenance activities or failures, must be recorded in a special database, preferably computerised, with the following information reported:

- location (station, stretch of line, track, tensioning length, span and mast),
- main technical and geometrical characteristics,
- date of first installation or last replacement,
- parameter measurements checked during observation, fault diagnosis runs, etc.,
- condition verified by inspections and observation,
- date and type of interventions (installation, painting, adjustment, calibration, replacement, lubrication, etc.),
- data of failure occurrences.

6.1 - Location references

The database must contain the minimum indications needed to localise the OCL objects along railway lines. In particular it is important to know where each object is located, for instance in a station or on a stretch of line, and to which asset, track, tension length, span or support it belongs.

6.2 - Characteristics and performance

The objects belonging to the families described in point 3 must be identified individually with a minimum of geometrical and technical data. This data is required in order to check the availability of the objects, plan maintenance activities, change components or materials and replace all or part of them.

6.3 - Age and condition

The year of the installation of components must be recorded in the database.

In some cases, it would be useful to record also the history of the place where the object is located; i.e. to report the date of the first installations and subsequent changes under planned renewals or as a result of failures.

Short notes should be given about the condition of these objects, availability and expected performance. These are related to the real situation of the installations or to the environment where they are located.

6.4 - Parameters, measurements and special evaluations

The database must contain all the parameters and sizes measured or evaluated during inspections, observations, recording runs and other activities (see point 4 - page 18).

The data measured automatically by fault diagnosis (using special trolleys, measuring coaches or fault diagnosis trains) must be recorded easily and the location of each entry identified. There must be a direct link between data measured manually and data checked automatically.

It is important to add the following information to that listed in points 6.1, 6.2 and 6.3 - page 33 for each object belonging to the families listed in point 3 - page 14.

The most important data to add about **supports** are:

- type and size of the support,
- number and other references,
- distance between the mast and the nearest rail,
- number, type and size of feeder cantilever,
- earth resistance with the date of measurement.

For **suspensions** it is important to note and record:

- type and size of the suspension,
- distance between contact wire and carrying cable,
- type and length of the tie bar,
- height, stagger and thickness of the contact wires under suspension,
- type and size of the catenary’s insulators, with the date of latest installation,
- type and size of the staggering insulators, with the date of latest installation,
- type and size of the feeder insulators, with the date of latest installation.

The main data to take into account referring to **spans** are:

- length of the span,
- height, stagger and thickness of the contact wires at mid-span,
- number and location of joints on contact wires and catenary along the span,
- number and location of broken strands in catenaries and other wires along the span,
- number and location of slack links or droppers along the span,
- number and location of hard spots along the span,

while for **particular spans** it is important to add information about:

- position of crossing and converging wires relevant to the outside temperature,
- condition and position of section insulators,
- electrical clearances in insulated overlap spans.

For **anchors** and **tensioning devices**, it is recommended to note:

- type and size of the anchor’s insulators, with the date of latest installation,
- position of weights in relation to temperature.

For **sectioning** and **feeding points**, it is necessary to report:

- type and size of devices,
- number of the circuit breakers and other references.

Concerning **return circuits** and **earth and protection circuits**, it is necessary to record:

- earth resistance measured, with the date of measurement,
- location and integrity condition of valves, diodes, etc.

All remaining equipment along the line belonging to the OCL installations must be reported in the database with the relevant main characteristics.

6.5 - Maintenance intervention data

The main information about maintenance interventions done (observation, checks, maintenance work and other preventive or corrective work) must be stored in the database.

The date is important for planning subsequent work or to modify the frequency adopted, to evaluate the necessity of the intervention and the opportunity to step up or reduce the maintenance activities (equivalent to raising or lowering the maintenance level).

For other strategic, statistical or economic considerations, but not technical, it is important to report the people responsible and the resources involved, the costs sustained, the work duration, the safety conditions and the occurrences of traffic interruptions.

The main data to be recorded after **inspections**, **observation**, **measurements** and other periodical or extraordinary verifications are:

- type and date of intervention,
- results of the work done in terms of brief information useful to update the database.

Also for **scheduled work**, it is important to link as well as possible the specific work done to the corresponding element recorded in the database. Otherwise it is useful to record information for strategic and economic considerations, such as:

- type and date of intervention,
- duration of the intervention,
- resources involved (personnel, equipment/vehicles, others).

The same data must be reported for **on-condition maintenance** together with the reason for the intervention.

Similar indications must be recorded for more extensive **extraordinary maintenance** and **renewal** interventions and for combinations of these, firstly to record the different OCL components replaced to increase the service life and/or the availability of installations.

For interventions carried out to **repair failures**, as explained in point 7 - page 37, in addition to all the previous information, the following must also be recorded:

- fault location,
- type and cause of the fault,
- direct and correlated responsibilities.

7 - OCL fault occurrences

When a fault occurs, it is not always possible to understand clearly the causes, effects and responsibilities, and at times the process needed to clarify the reasons for the fault is lengthy.

Nonetheless it is very important to analyse and record all the data relating to faults occurring, not only regarding the damage caused, but also the organisation adopted and all the other aspects involved, particularly regarding information that can be used as feedback for maintenance interventions, work organisation and in other sectors, to avoid repetition of the same type of faults or to reduce the volume of damages and the relevant consequences on train traffic.

Timely, comprehensive data input into an optimised statistics database will make it possible to examine, plan, experiment, promote and carry out appropriate countermeasures or interventions of different types more effectively, such as improving technical or maintenance standards, adjusting organisation, correcting regulations, developing relations with other related areas.

At the same time, it is useful to develop the data recorded and the statistics compiled in a uniform manner in order to be able to make objective comparisons easily.

7.1 - Failure database

A failure database must consist not only of the data needed regarding failure occurrences and recovery, but also of data relevant to the times and methods of intervention, the duration of disruptions, damage to installations, consequences on traffic and the responsibilities ascertained.

A failure report must be completed with general data referring to the organisation involved and to the structures and/or subjects concerned in the different reporting and analysis stages. The following specific data on failures occurring must be recorded:

- the classification among the types of failures (see point 7.2 - page 38),
- a short description of the failure and the relevant facts connected with it,
- the estimated or precisely defined causes of the failure,
- the sequences of the failure and its duration, including the time at which it occurred and other relevant facts about any subsequent faults occurring and/or repaired,
- the location of the failure in relation to the installation (line section, station, rail number, sector of contact line, mast number, etc.),
- the organisation adopted to repair a failure and relevant means and times of intervention from the call to personnel to the assembly point,
- the description of the intervention activities from the arrival at the fault location to the restoring of the installations (means used, number of workers and work controller, time taken to repair the failure, etc.),
- data about the line sections closed to train traffic (electric and not electric),
- weather conditions, before the failures and during the works,

- damage caused and the materials replaced or repaired,
- injuries,
- the total cost of damage and repair.

Presumed faults

In addition to the "real" faults, or to the faults which really occurred, for which the maintenance personnel has found real damage and spent time repairing the failure and restoring the installations, it is also possible that during the intervention no failures were seen and the OCL was restored without any manual work being carried out.

In these cases the maintenance staff concludes that the installations were found to be in sound condition and the causes of the "presumed fault" are attributed to absolutely transitory reasons (such as self-restoring insulation, overload instead of short circuit, wrong indications received, etc.).

These occurrences, too, must be recorded in the fault database to justify the delays produced in train traffic, which must always be safeguarded. In fact, similarly to real faults, these "no-faults" may cause disruptions, which generally are smaller than the real ones, but nonetheless important to be taken into account in order to take the appropriate countermeasures to reduce these occurrences.

7.2 - Failure classification

As mentioned above, faults occurring must be classified into several main types depending on the responsibilities attributed initially, usually divided into "internal" or "external" to the railway transport system and organisation.

In the internal responsibilities it must be possible, firstly, to identify the faults caused by the infrastructure system (installations, materials, organisation, personnel activities, etc.) such as:

- manufacturing defects, for example defective materials,
- poor installation work done by railway personnel or sub-contractors,
- poor maintenance work or surveillance,
- incorrect operation of the OCL network, such as wrong connection by remote electro-dispatching staff.

When responsibilities are attributed to infrastructure personnel, it is necessary to distinguish between:

- personnel generally employed in OCL maintenance,
- personnel involved in maintenance of other electrical installations,
- personnel responsible for track maintenance,
- other personnel working for the infrastructure system.

Among the faults due to other internal causes, it is important to underline the responsibilities of the structures and the relevant personnel involved in train operation and in the transport companies which caused the faults as a result of:

- incorrect operations in train traffic control,
- wrong behaviour of the personnel of the traction companies (e.g. pantograph damaged or driver responsibility),
- poor standard of work done by transport company personnel (e.g. loads not properly secured by freight companies).

The responsibility for faults is to be attributed to external causes when the latter are completely independent of railway structures, such as:

- bad weather or environmental reasons (e.g. storms, birds, trees, ice, high temperatures, etc.),
- interference by users,
- accidents such as level crossing collisions,
- acts of vandalism (e.g. objects thrown on the OCL, theft, etc.),
- works done near railway lines.

Similar responsibilities can be attributed for the causes of the "no-faults" described in "Presumed faults" - page 38.

7.3 - Failure statistics

Failure statistics are normally compiled with all the data mentioned above for different purposes or types of examinations.

In particular, the same statistics are usually analysed by experts in the different railway structures to research and develop the best countermeasures to propose, experiment and adopt for decreasing the probabilities of fault occurrence and/or reducing the degree of damage and disruptions to train traffic.

At the same time, simple statistics should be compiled which are easy to interpret immediately in order to assess trends in quantity and in the type of fault occurrences per year throughout an electrified network using special indicators to make the usual comparisons of data.

7.3.1 - The main indicators

The smaller set of statistics needed for an initial approach in analysing and comparing fault data should be compiled taking into account special parameters concerning the number of fault occurrences per year and per unit of length on the electrified network.

In particular, the main indicators generally used are as follows:

- *total OCL faults per year*, i.e. the total number of all faults occurring in one year in an assigned network of OCL or in a pre-determined part of it;
- *total delay*, i.e. the total time (in minutes) of the delays accumulated by all trains involved in the above OCL faults;
- *number of OCL faults per year and per 100 km*, i.e. the average number of faults occurring during one year, with reference to 100 km of OCL;
- *average OCL fault duration*, i.e. the mean time calculated for all faults occurring per year;
- *trains per OCL fault*, i.e. the average number of trains involved in a fault occurrence;
- *average delay per train*, i.e. the average delay accumulated by the trains involved in all the faults occurring in a year;
- *total costs sustained per year and per 100 km*, i.e. all the costs attributed to fault repair, including damage and loss of income.

Clearly, the above parameters calculated for different types of lines can be useful in investigations and comparisons of specialised aspects of details, starting for example from the analyses of statistics data about lines with similar technical characteristics or traffic densities (see point 5 - page 28).

7.3.2 - The percentage distribution

The above statistics are generally combined with the percentage distribution of the main types of faults in the most important fields of responsibility listed in point 7.2 - page 38.

As shown in Table 3 - page 42, firstly all OCL faults are divided in two groups, depending on the responsibilities attributed to:

- *internal causes*, with the percentage of faults directly or indirectly linked with responsibilities inside the railway system and organisation,

- *external causes*, with the percentage of the faults linked with responsibilities outside the railway system.

Within the group of internal faults, it is necessary to separate responsibilities, taking also into account as best as possible the new interoperability railway sub-systems (structural and operational), as follows:

- the *energy system*, for faults occurring in electric traction installations or due to the relevant personnel involved,

- the *infrastructure system*, for faults caused by problems in the infrastructure sector (tracks, tunnels, bridges, civil engineering),

- *other installations*, for faults occurring to remaining electrical installations (control-command, signalling, telecommunications, lighting and others) or due to the relevant personnel involved,

- the *traffic system*, for faults caused by lacks in the operating organisation (traffic controllers, station personnel, routing and traffic rules, etc.),

- the *transport companies*, for faults caused by deficiencies in rolling stock and transport organisations (locomotives, pantographs, drivers or train crews, poorly secured loads, rules, etc.).

Table 3 : The main causes of OCL faults

INTERNAL			
INFRASTRUCTURE AND INSTALLATIONS	**Energy system**	**OCL**	Design
			Construction
			Maintenance
			Materials
			Organisation
		Electric traction system	Remote control
			Others
		Others	
	Infrastructure (track, tunnel, bridge, civil engineering)	Track work	
		Others	
	Other installations (control-command, signalling, lighting, etc)		
TRAFFIC	Traffic operations		
	Others		
TRANSPORT COMPANIES	Rolling stocks	Faults on board	
		Others	
	Pantographs	Broken pantograph strips	
		Others	
	Others		
OTHERS			
EXTERNAL			
WEATHER/ ENVIRONMENT	Bad weather		
	Environment		
	Others		
THIRD PARTIES	Accidents		
	Vandalism		
	Others		
OTHERS			

The faults attributed to *energy system* responsibilities must be separated into two groups as follows:

- the *OCL sector*, for faults produced by deficiencies in the OCL field (design, standards, construction, maintenance, materials, personnel and other resources, rules, etc.);

- the *electric traction system*, which includes faults occurring to the remaining electric traction installations (power supply and others) and due to the relevant personnel involved, such as the operators working at the electrical dispatching centre.

In the group of external faults, responsibilities must be separated as follows:

- *bad weather conditions*, for faults caused by exceptional climatic conditions (earthquakes, storms, wind, ice, heat, etc.),

- *extreme environmental conditions*, for faults caused by particular situations created in the vicinity of the railways (trees, birds, pollution, etc.),

- *behaviour of third parties*, for faults caused by people extraneous to the railway system (errors by third party operators near the railway lines, accidents by vehicles at level crossings or vehicles falling on railway lines, acts of vandalism, theft, etc.).

7.4 - Feedback on maintenance activities and interventions

In the group of internal faults presented in Table 3, OCL maintenance experts must examine as closely as possible the above percentage attributed to the *OCL sector*, with the relevant effects for the corresponding total number of faults occurring, trains involved and delays caused.

These faults must be separated usually according to the reason for the fault, i.e.:

- *design*, in order to design OCL installations better or differently;

- *construction*, in order to build OCL installations better or differently;

- *maintenance*, in order to better adjust maintenance activities in relation to the maintenance level assumed or initially chosen for the line examined (see point 5 - page 28), in other words, to raise or lower the maintenance level, varying the frequencies and the intensities of the activities to be performed;

- *materials*, in order to improve the availability of the components used, with the aim of reducing the probability of manufacturing faults;

- *organisation*, in order to organise corrective maintenance and failure repair resources better (equipment/vehicles, devices and other resources, personnel training, etc.).

Links between maintenance and failures

Particular attention must be given to evaluating the links between the maintenance organisation and the results achieved in terms of failure occurrences, damage suffered, trains involved, costs sustained, etc.

For these reasons, the indicators in point 7.3.1 - page 40 could be suitably applied to better examine the problems arising and to re-plan maintenance activities as well as to assess resources and costs easily.

Consequently, from all the OCL failures occurring and the relevant statistics data, it is important to extract strategic information about:

- failures directly or indirectly due to OCL maintenance activities and organisation, to be able to compare this data with the results expected (according to the maintenance level chosen or negotiated and agreed in advance);

- failures due to other causes, where the maintenance organisation did not function effectively for repairing these faults, leading to further damage, delays and costs.

Lastly, great importance must be attached to failures that could have been avoided and/or where damage could have been lessened, with appropriate modifications to the maintenance organisation or suitable improvements to the installations in order to better negotiate the maintenance level and/or to plan the interventions considered necessary with the best use of maintenance resources.

8 - Safety conditions

To work on the OCL and, in particular, near live conductors, it is necessary to have a good knowledge of the safety conditions regarding personnel which might relate to:

- the work organisation and the type of work to perform,
- the distance from tracks open to traffic and from live conductors,
- the characteristics and scale of the means adopted,
- the knowledge of the workers.

Clearly, the best work conditions are when traffic is stopped completely, with all conductors cut out and earthed, with specialised workers and the proper equipment, in daylight time and with long track possession periods. The worst conditions are when adjacent tracks remain open to traffic at the maximum line speed, the other conductors are live, at night time with bad weather conditions and short track possession periods.

The requirements for maintaining occupational safety on OCLs and in the near vicinity are usually established in standards, national laws, internal rules, instructions and recommendations.

8.1 - Potential sources of danger

During work on electric traction lines or in their vicinity, the danger for the safety of personnel may depend essentially on the OCL's electrical and mechanical characteristics and the state of the installations, the railway environment and train traffic, work conditions, etc.

Dangerous conditions due to the characteristics of the electrical installations include the following, with some differences for DC and AC traction systems:

- the OCL layout and geometry (positions of the energy and earth conductors, position of the insulators, characteristics of the earth and return circuits),
- the voltage between OCL and rails, catenary and feeder, feeder and rails,
- the values expected for operational and short circuit current,
- the definition of the sectors fed, out of service and/or short circuited,
- the presence of other live conductors supported by the same masts or crossing the spans concerned,
- exposure to electric and magnetic fields,
- the rail-earth potential,
- the voltage induced on the OCL conductors,
- the probability of capacity charging,
- the inter-working between the electrical dispatching personnel and work gangs.

Dangerous conditions due to the mechanical characteristics of the OCL include:

- the presence of high tensioning in the wires on which the works are carried out,
- the unlacing of wires or other tensioned components that may hit workers and cause falls.

Dangerous conditions due to the railway environment include:

- traffic on tracks adjacent to the track where the works are carried out,
- the type of trains worked on the adjacent tracks and train speed,
- the risk that a train could be routed on the track where work is under way,
- the inter-working between the traffic controller and the work gang,
- the inter-working between railway personnel or contract personnel, works companies and third parties,
- the type of worksite protection.

Dangerous conditions connected with the works carried out may be due to incorrect behaviour by workers regarding:

- the work preparation (the part of the OCL switched off for the type of work in hand, the process of switching off the OCL performed properly),
- the work organisation and operation (work supervisor, distribution of tasks and responsibilities, use of protective belts and special equipment),
- the means adopted and their characteristics and performances (vehicles, ladders, facilities),
- the fixing of the earthing and short circuit devices (between OCL and rail, feeder and rail, shunting of rails, shunting of metallic parts to earth, etc.),
- work in heights,
- the up and down movements of the work platforms,
- lifting of heavy and large materials up on the platform,
- walking or stepping on catenaries or on their parts,
- handling of long devices or materials.

Additional dangerous situations may be produced by weather conditions during the works, such as:

- heavy precipitation (rain, hail, snow),
- violent storms or strong wind especially for work gangs in work platforms,
- poor visibility (darkness, twilight, fog).

At least some considerations about the personnel background, competence and skills at all levels of responsibility should be taken into account, with particular reference to the:

- poor organising ability of the works manager,
- incorrect behaviour of the works controller,
- incompetency and carelessness of the workers,
- wrong employment of non-specialised personnel.

The risk analysis

Before starting any work on OCL installations, all potential risks which might affect the operators must be analysed and the relevant countermeasures organised.

Table 4 lists the above-mentioned main causes of risk for OCL workers together with the corresponding recommendations about the different countermeasures that can be adopted during the works.

The countermeasures recommended in Table 4 are given in decreasing order of effectiveness. Several of them may be applied at the same time.

The costs of the measures often depend on the type of protection chosen. The choice of the type of protection depends in turn on how long the operation takes to be carried out.

Table 4 : Risks for OCL workers and relevant countermeasures

Risks	Countermeasures
TO BE HIT BY TRAINS RUNNING ON ADJACENT TRACKS	- Stop train traffic - Introduce speed restrictions - Have a look-out announce oncoming trains - Use work trains and block access to the side adjacent to the other track - Erect protective barriers in the space between the tracks - Use of safety clothing
TO FALL FROM A HEIGHT	- Erect protective barriers on the working platform - Introduce collective protection measures on OCL installations - Use work trains with scaffolding structures or staff lifting ramps with collective protection - Use individual safety gear
ELECTROCUTION	- Switch off all power supplies and earthing - Install protective equipment (screens) on the OCL installations or on the work trains - Ensure that safety rules are observed (safety distances, equal potentials, etc.)
TO BE HIT BY OCL COMPONENTS	- Avoid mechanical pushing (conductors broken, tensioning on curves) - Use helmet and protective devices

8.2 - Safety measures

Clearly, to minimise the risk of accidents during the works, one or more of the safety measures recommended above must be adopted, even if productivity and the volume of work to be done is diminished as a result. In addition, new technologies and the best organisation could easily improve safety and make it possible to achieve the other aims of productivity and volume of work.

Depending on the measures chosen, the works must be organised thoroughly, considering all the aspects of the operational interventions namely:

- the situation regarding train traffic on the track where the work is carried out and on adjacent tracks,

- the state of the energised OCLs and other live electrical installations,

- the conditions of the resources to be used (personnel, equipment/vehicles and protective devices),

- the detailed sequences of the operations and of the scheduled activities.

8.2.1 - Track possession and train traffic

OCL maintenance works requiring use of circuit breakers switched off must be organised with a minimum track possession time, depending on the real possibilities for carrying out the intervention and re-opening the line at the maximum permissible speed. This is the result of a continuous compromise between the operating and the maintenance managements.

Safety conditions for personnel are ensured by the protection adopted for the worksite and by the precautionary measures taken in clearing the operating tracks of personnel and vehicles/equipment.

When during the interventions, the probability of entering accidentally onto the adjacent track is substantial and it is not possible to minimise the risk, the track possession must be extended to any other tracks concerned.

Among the measures applied to prevent accidents, train speed restrictions on the adjacent tracks can be introduced. In these cases, the speed restriction depends on the work to be done, the presence of tight curves, the distance between the centre lines of the relevant tracks, the particular difficulties in working during the night or under low visibility conditions, etc.

In the interventions for OCL construction or renewal, it could be recommended to restrict speed on adjacent tracks depending on the above particular situations.

At all events, on high speed lines, the interventions involving impinging on a track with personnel and trolleys are possible only after the speed on the other track has been reduced.

8.2.2 - Electrical safety distance

Activities involving manipulation of conductors, insulators and all live parts of the OCL which might accidentally become live or handling activities near live parts must be planned and executed to rule out any risk of direct or indirect electrocution.

This is done in accordance with the work organisation by adopting all the measures and precautions designed to ensure the safety of personnel operating beyond the electrical protection distance.

When during the interventions, the likelihood of entering into zones inside the safety distance becomes substantial and it is not possible to reduce the risk to zero, the work must be stopped or work continued after the circuit breaker has been extended to any other parts concerned, such as switching off and earthing the OCL on the adjacent tracks.

The safety distance is generally specified in European standards, national laws or internal regulations.

Appendix C - page 76 lists the electrical protection distances generally observed by the OCL specialist personnel during works on OCL installations in the different IMs.

8.3 - Skills and abilities of the personnel

The railway personnel employed in works on the OCL or near live electrical installations must be specially prepared and trained.

These workers must attend specific training courses and pass examinations to become specialised in the subject and their skills must be certified.

Their knowledge (about electrical diagrams and the real condition of the installation to be worked on, the working methods and procedures, safety rules, the equipment used, etc.) must be updated continuously.

Work on energised OCL

In some countries work on energised lines and live electrical installations is allowed provided special means and procedures are adopted. In particular, only authorised workers with previous training and special accreditation are allowed to work on energised OCL.

This type of work is permitted only using insulated ladders or vehicles equipped with special insulated platforms and after authorisation by the electrical dispatcher. In addition, as works on de-energised installations create habits different from works on energised installations, it is necessary to ensure a suitable break for the same workers before they work on energised OCL.

The general conditions for works on energised contact lines are defined in the national standards of the IMs concerned and usually specify the operations that can be performed on DC systems. In these cases, laws or special rules and instructions must in particular:

- define the qualification requirements for workers and foremen of working groups,
- require special insulating equipment and precautions to be taken before beginning the work,
- define conditions for ascent of workers to insulated platforms and for safe work on them,

- define conditions when the work on energised OCL with insulated equipment is prohibited,

- define conditions for safe descent from the platforms,

- define conditions for testing special insulated equipment.

8.4 - Safety improvement and relevant statistics

Each IM must pay maximum attention to occupational safety, devising and introducing any possible improvement to minimise continuously the risk of accidents to the workers.

This target must be reached with specific actions to be carried out, involving the entire railway organisation at all levels of responsibility. In particular the safety system must:

- ensure process control by the management at different levels,

- involve the staff and their representatives at all levels,

- strive continuously to improve safety.

The basic elements of the safety management system are:

- provision of staff training programmes and of systems to ensure that staff competencies are maintained and tasks carried out;

- arrangements for the provision of sufficient information within the organisation and, where appropriate, between organisations operating on the same infrastructure;

- procedures to ensure that accidents, incidents, near misses and other dangerous occurrences are reported, investigated and analysed and that necessary preventive measures are taken;

- provision of plans agreed upon with the relevant public authorities for action, issuing an alert and providing information in the event of an emergency.

It is very important to analyse and discuss among OCL personnel any accidents which have occurred and the countermeasures and recommendations to apply to avoid them in the future.

Lastly, it is strongly recommended that the IMs define agreed data to record the accidents occurring and compare statistics, with the common aim of improving continuously the safety of all personnel employed.

9 - Resources and costs

All activities and works needed to maintain good OCL condition and performances must be organised and carried out with the main aim to:

- ensure the maintenance level strategically chosen (planned maintenance, failure repair and other activities planned) line by line;
- ensure maximum safety for personnel and for train traffic during the works;
- require minimum track possession time;
- cause minimum disruption to train traffic;
- contain maintenance costs;
- contain total costs.

9.1 - Track possession

The most important resource for work on the OCL is determined by the availability of track possessions. In fact the best conditions for work without producing traffic disruptions with delays to trains are determined by the possibility of using intervals between trains defined in the timetable, preferably during day time and their acceptable duration.

The main aims to pursue in negotiations on the amount and duration of track possession for maintenance activities and other works on OCLs are:

- to achieve maximum productivity for the OCL maintenance personnel with one or more intervals during the working day;
- to concentrate on longer intervals during the weekend or at night;
- to ensure the minimum duration per interval;
- to coordinate planning of all the work that can be done in the same intervals (OCL, track, etc).

It is important to underline that the real time spent working (productivity) on the OCL during the track possession period depends on the technology used (remote control, telecommunications, etc).

9.1.1 - Duration of day and night intervals

Generally productivity, quality and safety are the optimum if the works can be carried out in daylight and in adequate, easily planned track possessions.

Quality and safety can be ensured also at night or in unfavourable traffic, speed and weather conditions, but all require the use of more considerable resources for lighting, protection etc., with the attendant higher maintenance costs.

The minimum productive duration of track possessions necessary for OCL maintenance is:

- 2 hours working time per track in daytime intervals,
- 4 hours working time per track in night time intervals.

In the event of short working times in intervals, it is important to plan more intervals in the same duty roster to ensure at least the minimum productivity for personnel, bearing in mind that the aim is for them to be able to carry out work on the installation for 60 % of the time they are on duty.

The largest interventions for extraordinary maintenance or renewals that could require longer track possessions generally need special planning.

9.1.2 - Maximum speed on adjacent tracks

It is self-evident that the works to be carried out and the resources involved increase with the line categories and the relevant maintenance level chosen, from A to E (see point 5 - page 28 and Table 2 - page 32).

When the line speed exceeds 160 km/h on tracks adjacent to the one where the works are carried out, speed restrictions may be required depending on the works involved and other conditions mentioned above.

On high speed lines (E), experience acquired suggests speed restrictions or line closure for all maintenance work carried out at night.

9.2 - Personnel

Normally the staff assigned to work on electric traction installations is specialised, well prepared, well-trained and certified.

The entire work organisation relevant to OCL maintenance must be defined, depending particularly on the main characteristics of the track possessions, the number and duration of these and the days and weeks in which they occur.

OCL personnel working time must be scheduled taking account, above all, of the main goals set, namely:

- maximum productivity possible in the work done with the track possession time available,
- the need to organise work duty rosters to ensure the interventions for fault repair within the times planned (availability of OCL personnel out of the maintenance activities).

Therefore the cost of OCL personnel is strictly dependent on the shifts planned for ensuring maximum employment during track possession and the necessary availability for surveillance and failure interventions, in according with the maintenance level chosen and the expected results.

Moreover, for working on OCL during track possessions and with traffic worked on the other tracks, it is important to organise the worksite taking account of all the personnel involved.

Hence, use of additional personnel and other resources must be considered for the protection organisation and subsidiary activities and this is generally more costly for work to be performed at night than in daytime.

9.3 - Means and equipment

To work effectively on the OCL and carry out the different tasks in the best way with maximum productivity, it is necessary to use the appropriate means as well as properly designed and technologically advanced equipment to reduce manual operations and working time, and to ensure maximum safety and easier work for the personnel involved.

In particular, vehicles should be properly equipped, with a moving platform to allow the workers to reach all OCL parts easily, both during planned works and during fault repair.

Rail vehicles must be able to reach the work site quickly in order to minimise access time in the work possession. They must be easily controlled at low speed for short movements within the worksite, preferably equipped with electric traction to reduce noise and pollution, mainly in tunnels.

In some cases, the availability of rail-road vehicles can be strategic to reach the worksite (mainly for fault repair, but also for scheduled work), after covering by road the longest possible distance and entering onto the railway line at the nearest suitable accesses (stations, level crossings etc.) in order to minimise access time during the track possession period, especially if there is little time available for mounting onto the railway line and the relevant operations are simple.

Lastly, it is important to bear in mind the need for equipment, instruments and tools that are properly protected, efficient, practical and suitable for all the works to be performed in order to reduce working time, and increase safety and productivity during the track possession periods.

For verifications, measurements and monitoring operations, it is advisable to consider use of purpose-built trolleys, vehicles and equipment depending on the objectives set case by case; advances are being made continuously in the technology and performance of this equipment.

9.4 - Costs

As mentioned above, the cost of the OCL maintenance organisation is influenced by a large number of variable parameters, in particular, costs increase with:

- the degree of the maintenance level chosen,
- shorter track possession intervals,
- the time of the track possessions (night time),
- traffic density and train speed on adjacent tracks,
- the additional personnel necessary for providing protection, lighting, etc.,
- the other activities that the OCL personnel must perform (fault repair, renewals).

Conversely, costs decrease with:

- longer track possession intervals,
- the time of the track possessions (daytime),
- the use of automatic protection for the worksite,
- the quality of the equipment/vehicles and technology adopted.

To define maintenance costs clearly and better appreciate their impact on the total costs sustained by IMs, it is important to calculate the costs for the track involved from time to time, considering the loss of income due to interruptions in train traffic or because traffic was subject to speed restrictions (cancelled trains and/or additional costs for replacement services).

9.5 - Maintenance indicators

To develop a benchmark of maintenance data, special parameters relating to the maintenance level targeted and the relevant costs to be sustained must be taken into account.

In particular, the main indicators generally used to analyse the situation are as follows:

- *personnel per 100 km*, i.e. the average number of workers employed for 100 km of OCL, to ensure the expected maintenance level on the relevant type of OCL, from A to E category lines;
- *daily, nightly and periodic track possession duration*, i.e. the average duration of the track possessions for the maintenance work done on the OCL during daytime, night time and on the weekend;
- *number of track possessions per 100 km of OCL*, i.e. the total number of the track possessions per year for OCL maintenance work, preferably divided up according to the period at which it is carried out (daytime, night time and on the weekend);
- *man hours of track possessions per 100 km*, i.e. the hours per year of work in the intervals used for maintenance activities on 100 km of OCL, depending on the maintenance level (from A to E);
- *costs per 100 km*, giving the average total costs sustained for the entire maintenance organisation and resources for 100 km of OCL (personnel, materials, vehicles and equipment), depending on the maintenance level (from A to E).

Distribution of activities

As already mentioned, the OCL personnel is normally employed for carrying out all the work and maintenance activities mentioned in point 4 - page 18 (inspections and observation, checks and measurements, scheduled and on-condition maintenance, fault repair and special work).

At all events, it is important to define a few additional indicators which are especially useful to understand and analyse the main levers in negotiations on maintenance levels, the number and duration of track possessions, labour requirements, equipment/vehicles required, other resources etc.

The total number of working hours, taking account of the manpower available in the year, must be distributed according to the plan of activities agreed, in particular it will be necessary to assign the cumulative working hours per year and per type of activities and/or to fix the percentage of working time planned for any activity to be carried out with or without track possession.

To achieve these aims, the most appropriate indicators, derived from those mentioned above, could in particular define the manpower employed in the different main groups of activities encompassed by strategic maintenance policies, beginning with the choice of the maintenance level, such as the:

- *man hours for preventive maintenance*, i.e. the total number of hours planned or reported to carry out all preventive maintenance activities (such as inspections, measurements and scheduled operations) per 100 km of OCL and per year, operating both with and without track possession;

- *man hours for corrective maintenance*, i.e. the total number of hours planned or reported to carry out corrective maintenance activities (such as on-condition interventions, fault repair, etc.) per 100 km of OCL and per year, operating both with and without track possession;

- *man hours for other activities*, i.e. the total number of hours planned or reported to carry out other ad hoc work planned (such as extraordinary maintenance, renewal intervention etc.) with and/or without track possession.

From the analysis of these parameters, it is immediately evident, for instance, that by increasing the proportion (or percentage) of preventive maintenance activities (i.e. increasing the maintenance level), a reduction in fault repair work is expected and vice versa.

Appendix A - OCL diagrams and drawings

Appendix A contains diagrams and drawings showing the main parts and components of the OCL, to provide an overview of the objects considered.

In particular, the following figures provide readers with the opportunity of acquiring practical knowledge of the definitions used frequently in the leaflet:

point A.1 - page 57	shows diagrams of support structures frequently encountered, with reference to point 3.1 - page 14;
point A.2 - page 58	shows the type of suspensions frequently encountered together with their components, as defined in point 3.2 - page 14;
point A.3 - page 59	contains two typical diagrams of spans (see point 3.3 - page 15) as examples adopted in AC and DC systems, with the definitions of the main components;
point A.4 - page 60	shows special types of spans (see point 3.4 - page 15) requiring specific attention in maintenance activities;
point A.5 - page 61	contains a diagram of a tensioning length of OCL with the anchors and the tensioning devices mentioned in point 3.5 - page 16;
point A.6 - page 62	shows a diagram and a mast equipped with two disconnectors for sectioning and feeding points, as seen in point 3.6 - page 16;
point A.7 - page 63	shows a section of rail line fed in DC current with the relevant return circuit mentioned in point 3.7 - page 16;
point A.8 - page 64	shows a section of rail line fed in DC current with its earthing and protection circuit (see point 3.8 - page 17);
point A.9 - page 65	shows two sections of OCL (outside and inside a tunnel) to provide an overview of the main components used

A.1 - Support structures - Supports et armements - Stützstrukturen

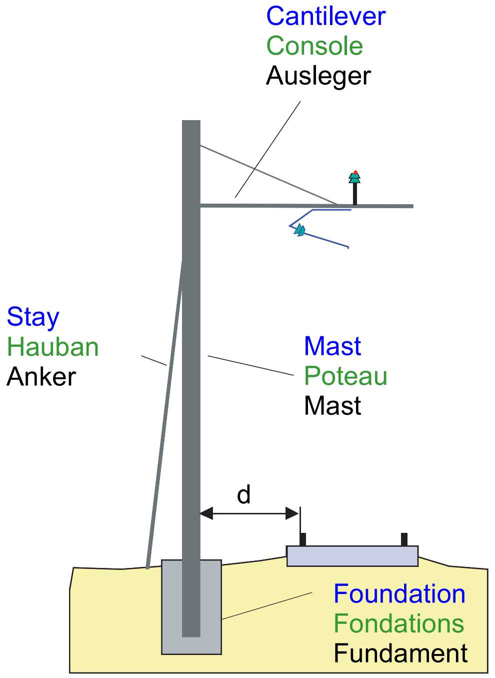


Fig. 1 - Mast - Support - Mast

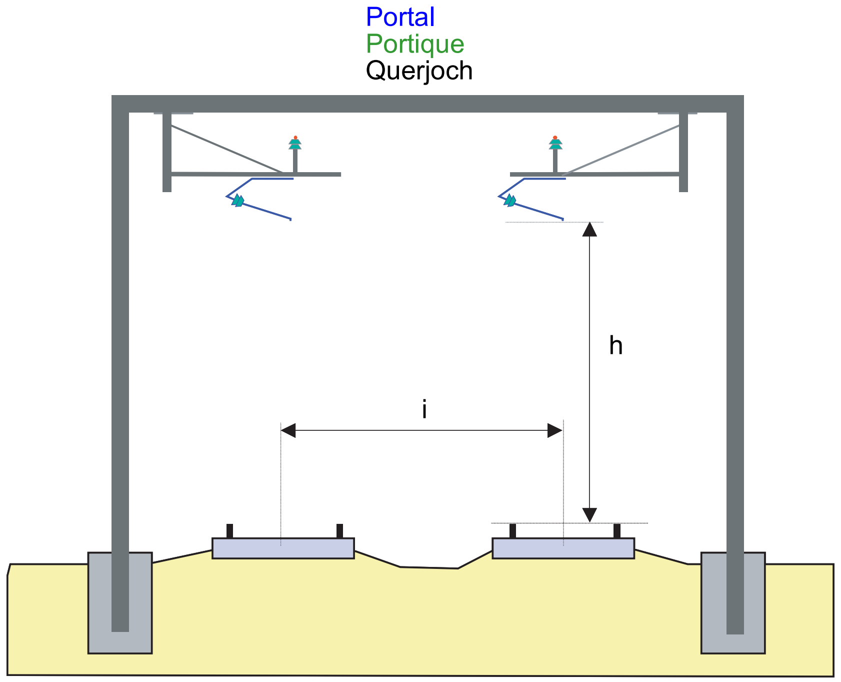


Fig. 2 - Portal - Portique rigide - Querjochtragwerk

d = distance between mast and the nearest rail
distance entre poteau et rail le plus proche (implantation)
Abstand zwischen Mast und nächstliegender Schiene

i = distance between track centre-lines
distance entre axes de voie
Abstand zwischen den Gleismittenachsen

h = height of the contact wire
hauteur du fil de contact
Fahrdrahthöhe

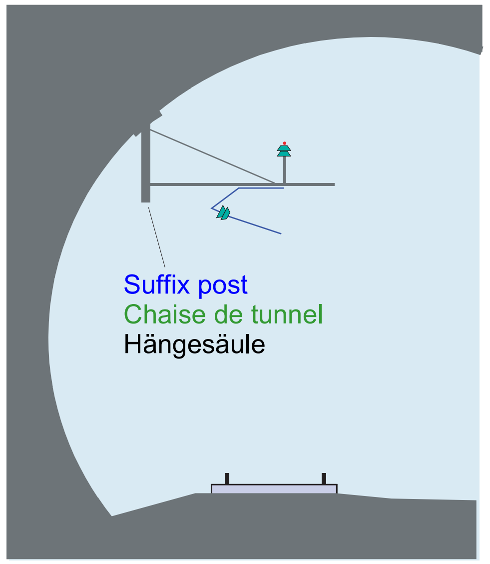


Fig. 3 - Tunnel support - Suspension sous tunnel - Tunnelstützpunkt

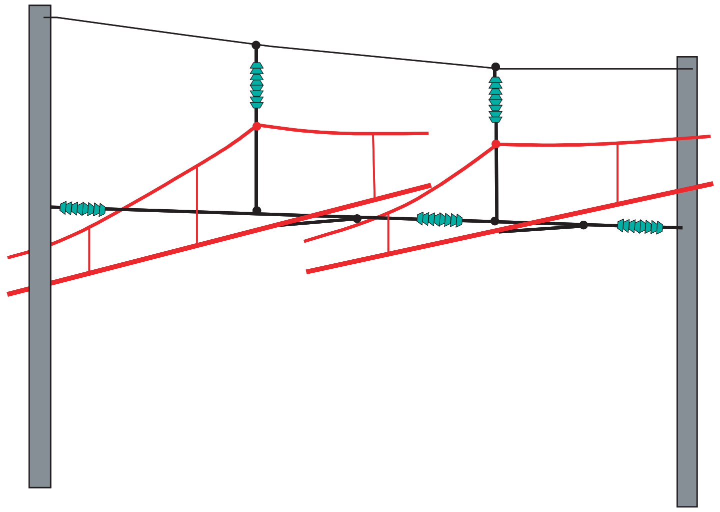


Fig. 4 - Headspan suspension - Portique souple - Querfeldaufhängung

A.2 - Suspensions - Suspensions - Stützpunkte

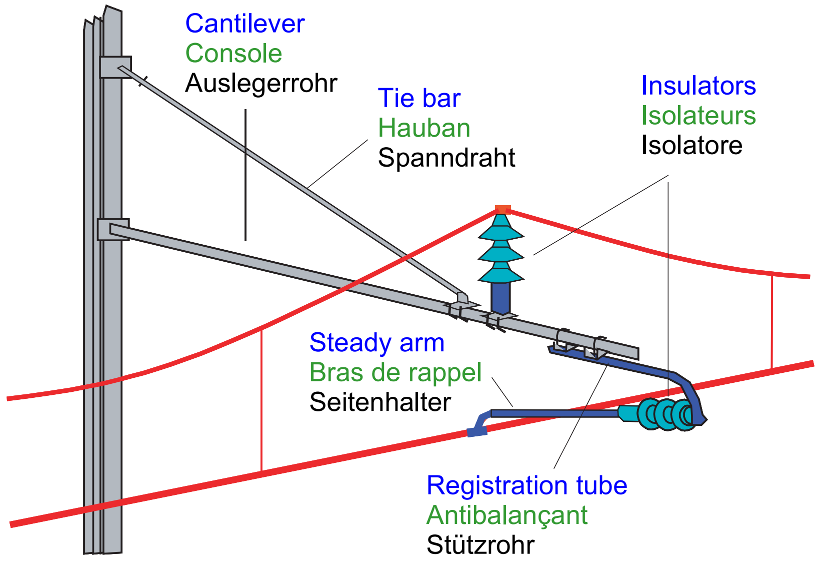


Fig. 5 - Cantilever - Console horizontale - Ausleger

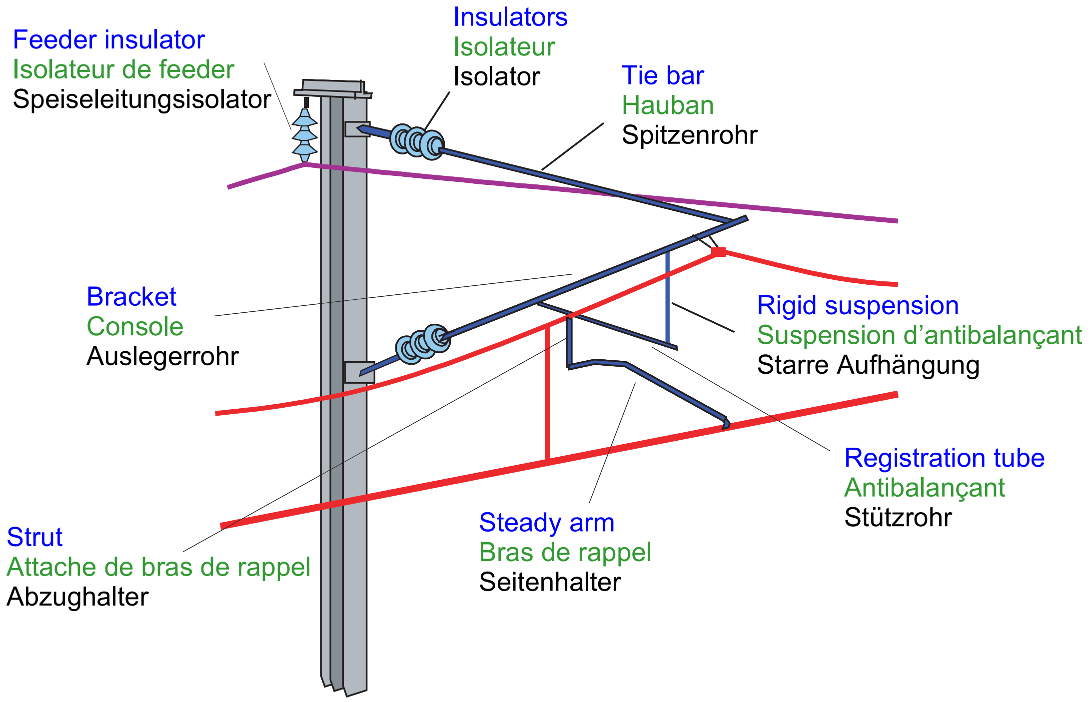


Fig. 6 - Insulated cantilever - Console inclinée isolée - Bahnsteigausleger

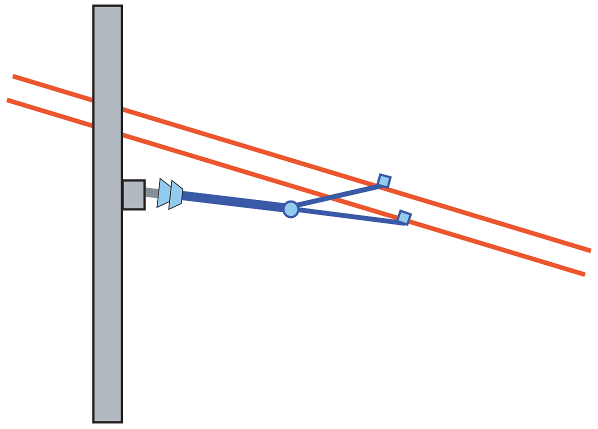


Fig. 7 - Pull-offs - Rappel direct - Bogenabzug

A.3 - Spans and relevant elements - Equipement d'une portée de caténaire - Feldlängen und ihre Elemente

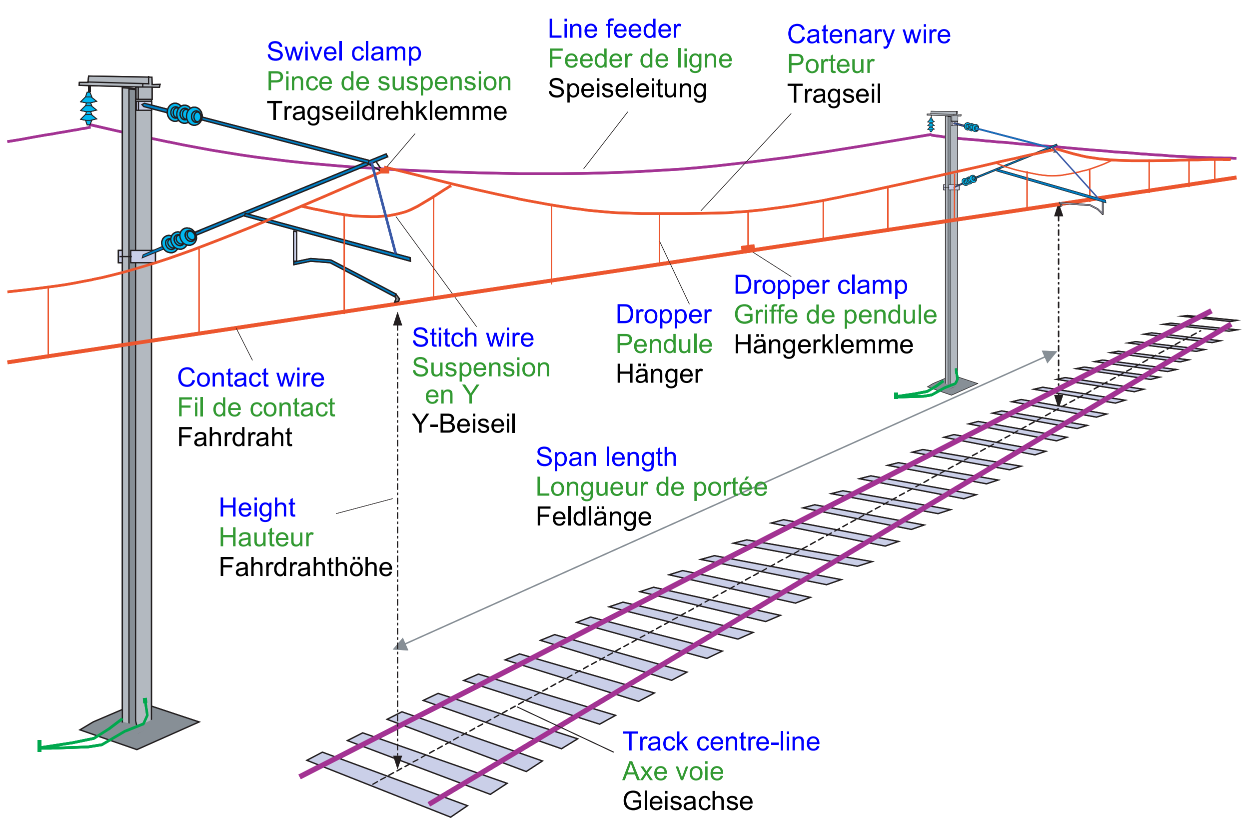
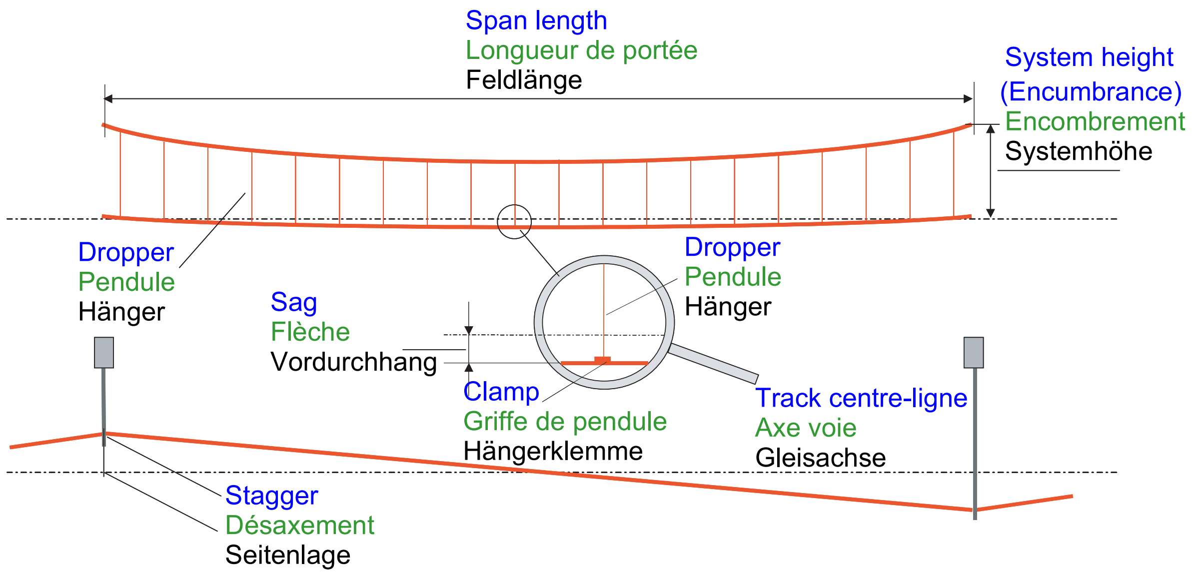


Fig. 8 - AC system - Portée de caténaire alimentée en courant alternatif - Wechselstromsystem



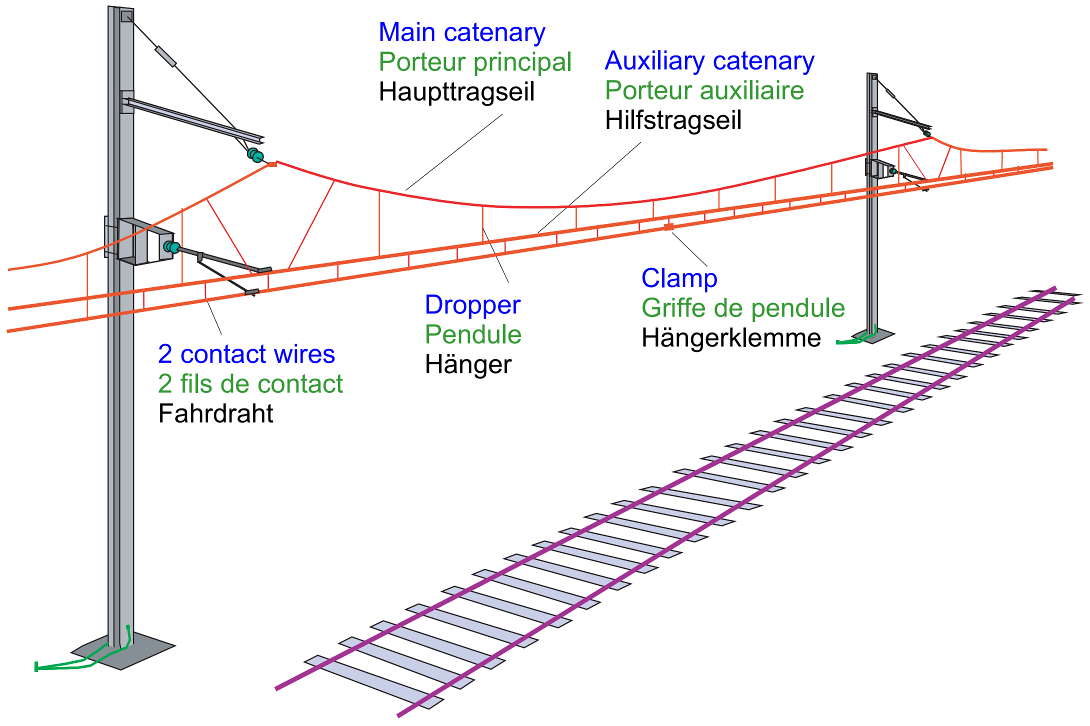


Fig. 9 - DC system - Portée de caténaire alimentée en courant continu - Gleichstromsystem

A.4 - Special spans - Portées particulières - Spezielle Feldlängen

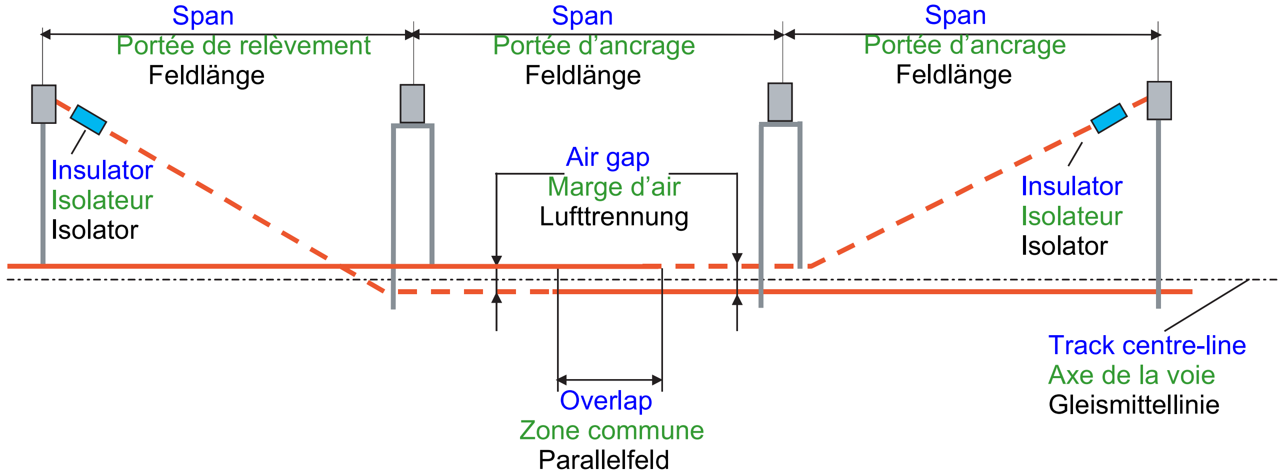


Fig. 10 - Overlap span - Zone d'ancrage à lame d'air - Parallelfeld

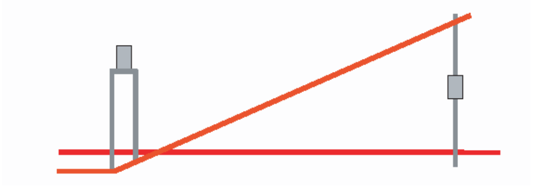


Fig. 11 - Overhead crossing - Caténaire d'aiguillage - Fahrdrahtkreuzung

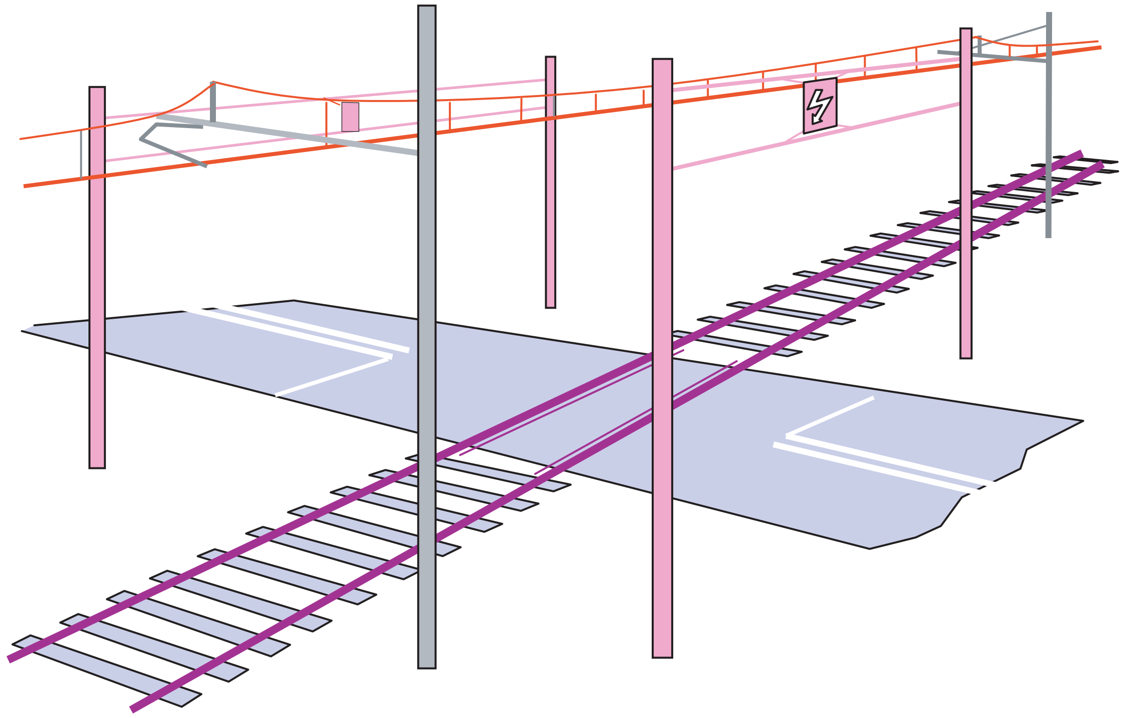


Fig. 12 - Level crossing - Passage à niveau - Bahnübergang

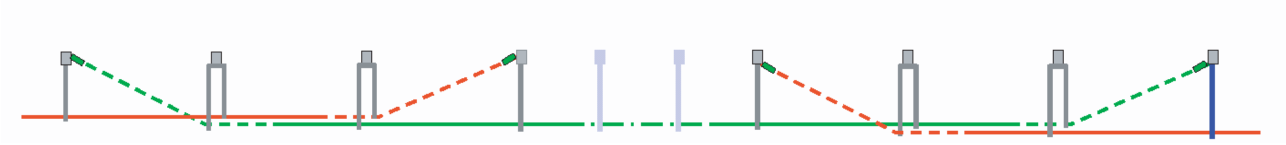
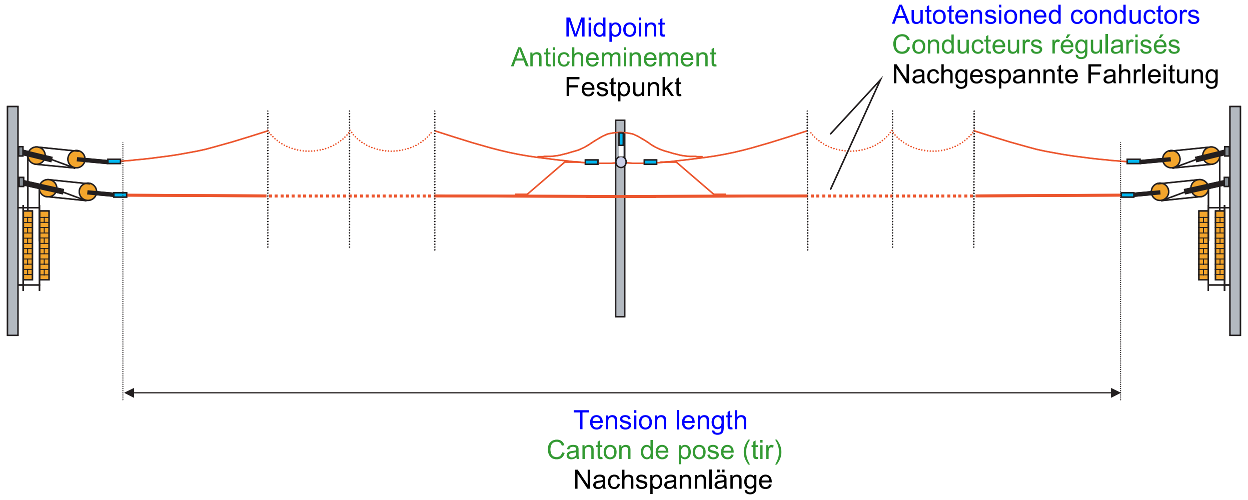


Fig. 13 - Neutral section - Section de séparation - Schutzstrecke

A.5 - Anchors and tensioning devices - Ancrages et appareils tendeurs - Anker und Nachspanneinrichtungen



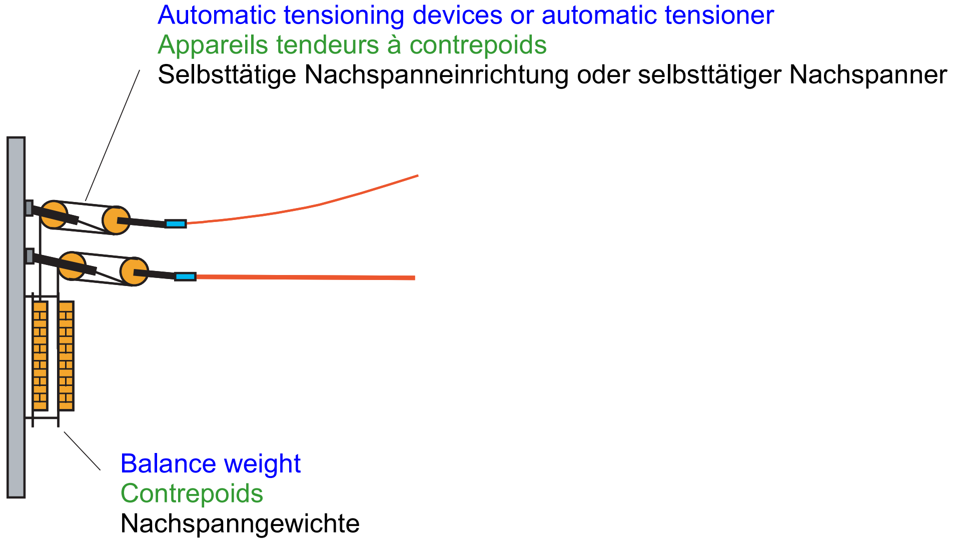
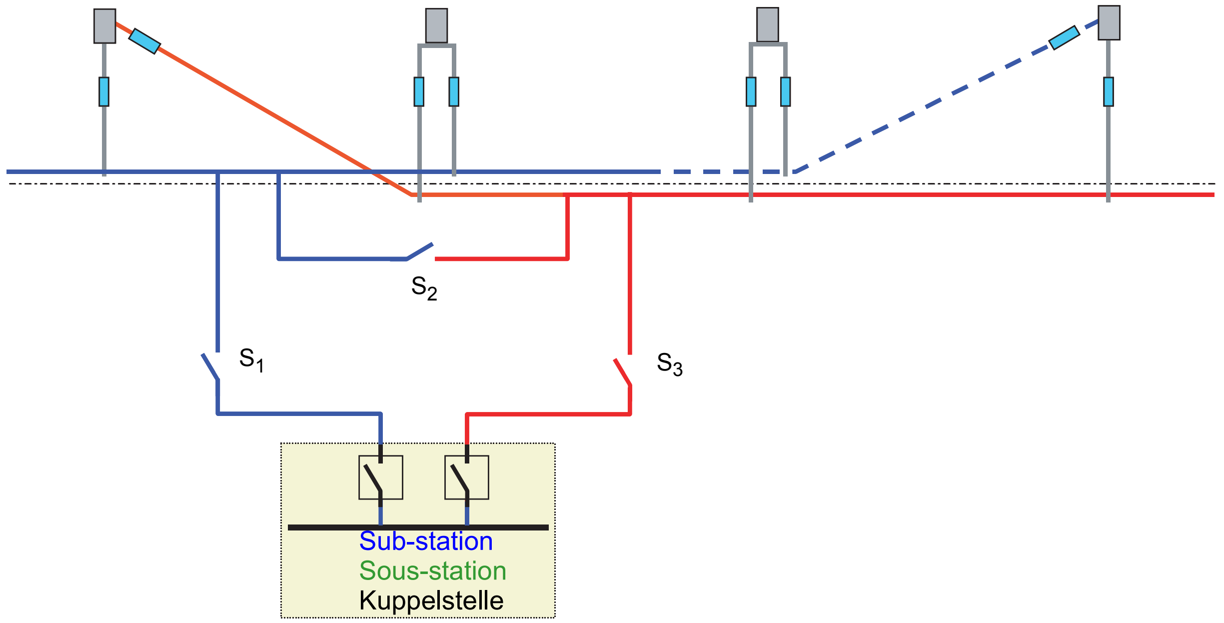


Fig. 14 - Anchors and tensioning devices - Ancrages et appareils tendeurs - Anker und Nachspanneinrichtungen

A.6 - Sectioning and feeding point - Pontage et alimentation - Trennstelle und Speisepunkt



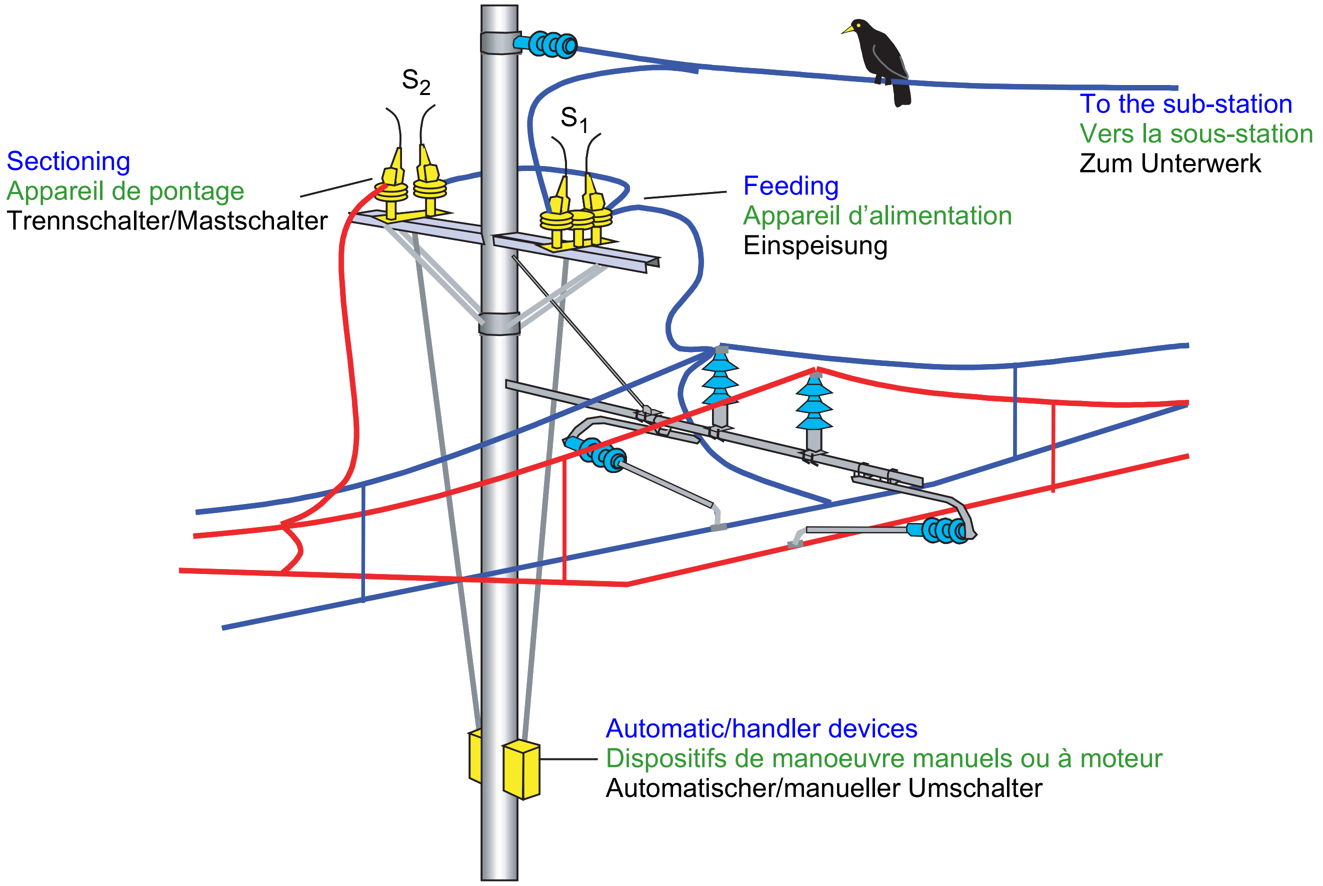


Fig. 15 - Sectioning and feeding point - Pontage et alimentation - Trennstelle und Speisepunkt

A.7 - Return circuit - Circuit de retour du courant - Rückleitung

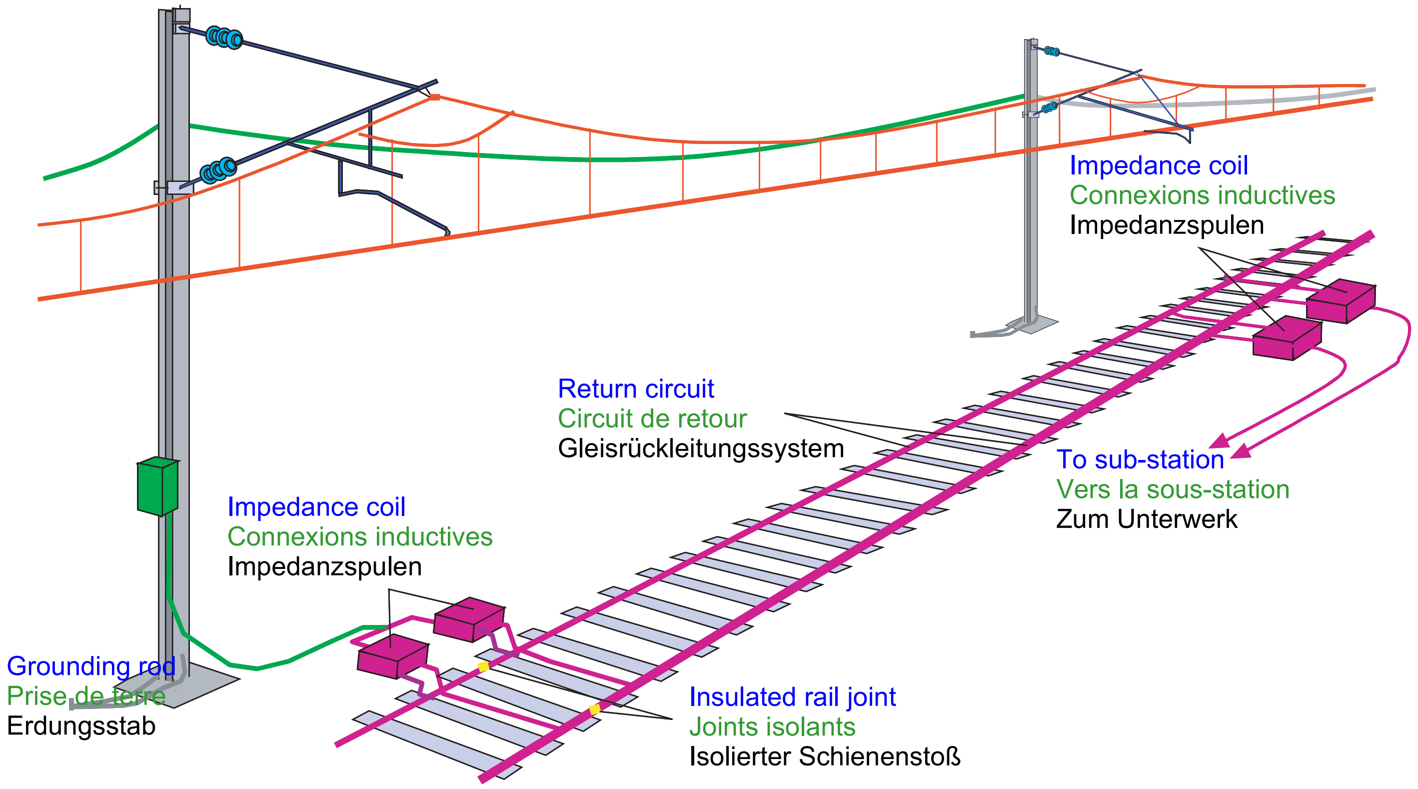


Fig. 16 - Return circuit - Circuit de retour du courant - Rückleitung

A.8 - Earthing and protection circuit - Circuit de mise à la terre et de protection - Erdungs- und Schutzstromkreis

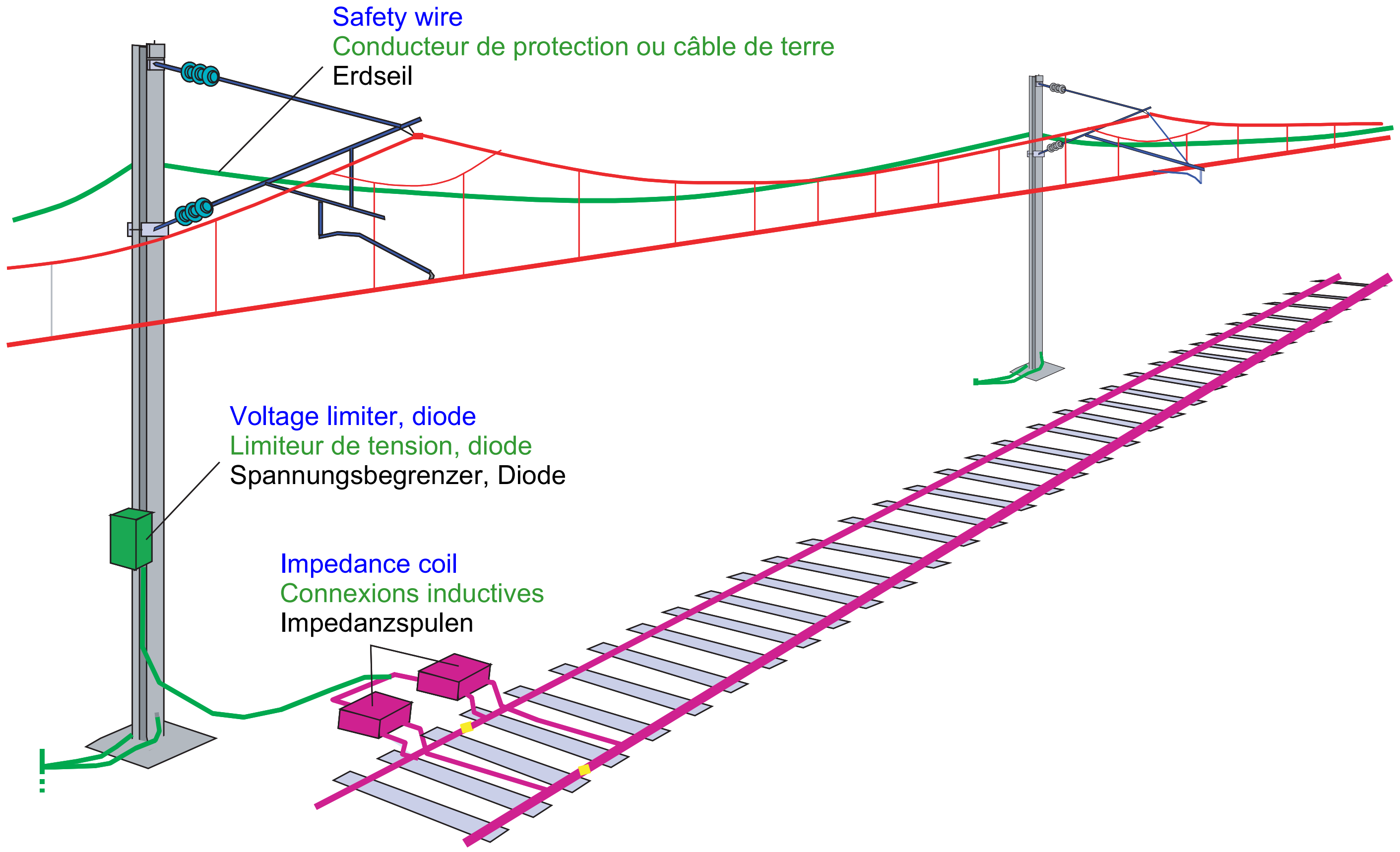


Fig. 17 - Earthing and protection circuit - Circuit de mise à la terre et de protection - Erdungs- und Schutzstromkreis

A.9 - Sections of OCL - Caténaires en extérieur et en tunnel - Oberleitungsabschnitte

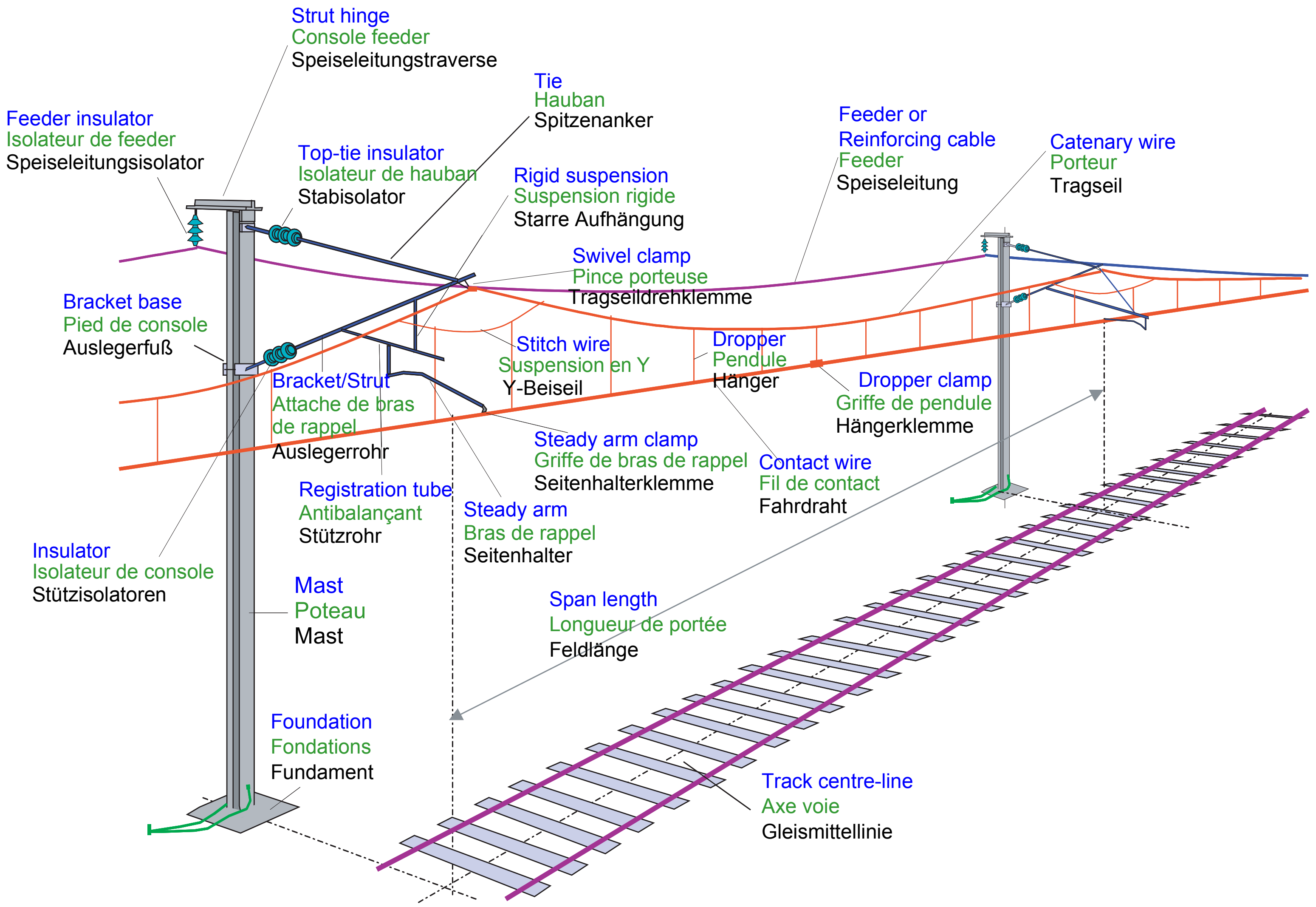


Fig. 18 - Section of OCL in open air - Caténaire en extérieur - Oberleitungsabschnitt im Freien

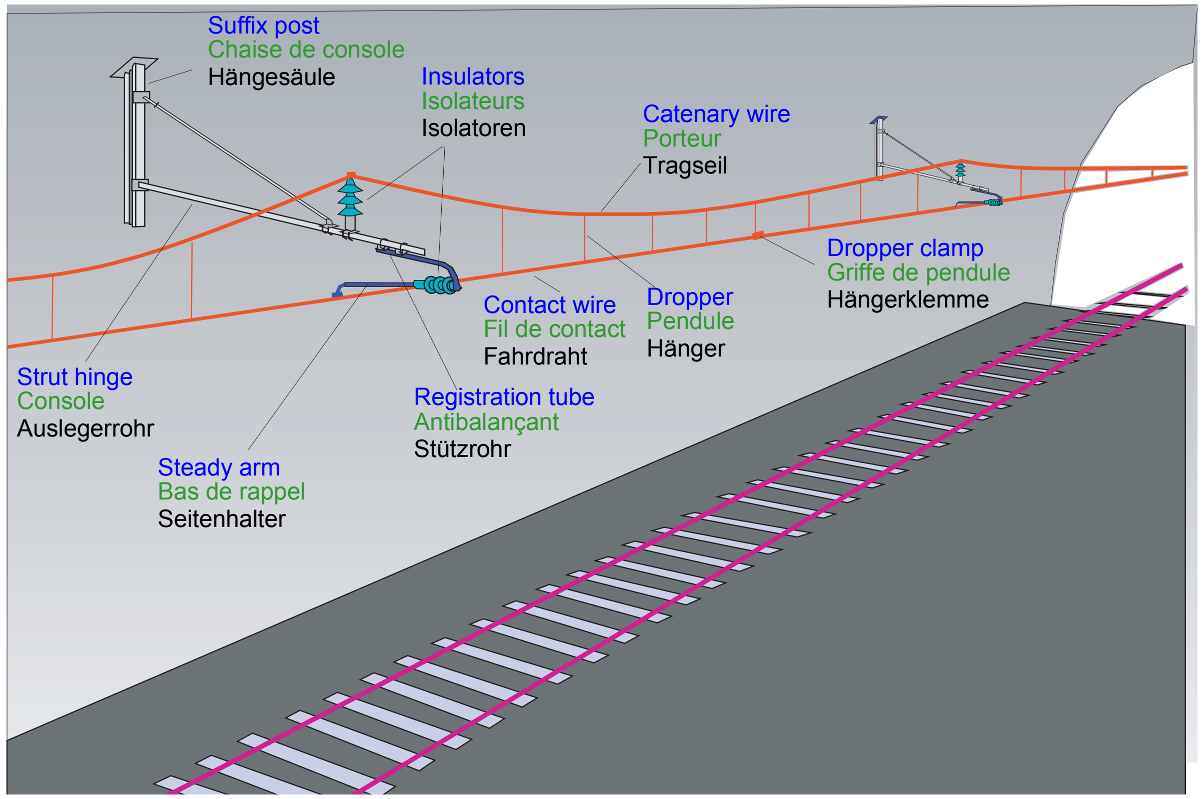


Fig. 19 - Section of OCL in a tunnel - Caténaire en tunnel - Oberleitungsabschnitt in einem Tunnel

Appendix B - OCL characteristics and performance

This Appendix contains descriptions of the main characteristics of the OCLs adopted by the different IMs.

In particular, there are one or more tables for each IM network depending on the different electric traction systems (1,5 kV DC, 3 kV DC, 15 kV AC and 25 kV AC) in use, as shown in the following summary overview.

IM	**Country**	**Electric traction systems**			
		1,5 kV DC	**3 kV DC**	**15 kV AC**	**25 kV AC**
CD	Czech Republic		Table 1		Table 2
CFF-FFS-SBB	Switzerland			Table 3	
DB-Netz	Germany			Table 4	
ÖBB	Austria			Table 5	
PKP	Poland		Table 6		
ADIF	Spain		Table 7		Table 8
RFI	Italy		Table 9		Table 10
INFRABEL	Belgium		Table 11		Table 12
SNCF/RFF	France	Table 13			Table 14
ŽSR	Slovak Republic		Table 15		Table 16

The tables that follow are designed to facilitate comparisons of the most important data on the railway lines and traffic together with the OCL characteristics generally adopted.

The line characteristics are defined in terms of:

- *maximum speed*, in km/h or in the speed brackets in point 5.2 - page 28, for which the line has been designed;
- *traffic density* on the line in terms of number of trains and/or pantographs per day and per track, as described in point 5.3 - page 29.

The OCL characteristics are given by the main data that qualify the electrical, geometrical and mechanical performances of the contact line, such as:

- *total section*, in mm^2 of equivalent copper section, considering all the energy conductors installed (carrying cables, contact wires and feeders);.
- *catenary data,* with the number of carrying cables, their chemical composition, section, mechanical tension and the presence of stitch wires;
- *contact wire data,* with the number of shaped wires, their chemical composition, section and mechanical tension;
- *feeder data,* with the number of cables, their section and chemical composition, taking into account that the reinforcing feeder section increases the total section of OCL. The section of the feeder of the 2x25 kV system is not included.

The last column “notes” contains the national code of the relevant OCL standard described on the same row.

Table 1 : 3 kV DC systems on ČD (Czech Republic)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section $[mm^2]$	n°	chemical composition and section $[mm^2]$	n°	chemical composition and section $[mm^2]$	tension [daN]		stitch wire Y/N	n°	chemical composition and section $[mm^2]$	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160	low		270			1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	medium		412,2	1	Al Fe 240	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	high		554,4	2	Al Fe 240	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
160	medium		390	1	Cu 120 [a]	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	high		510	2	Cu 120 [a]	1	Cu 120		1 500	Y	1	Cu 150		1 500	J

Equivalent Al Fe 240 $\approx$ 142,2 mm^2 Cu (1 mm^2 Al Fe 240 $\approx$ 0,59 mm^2 Cu)

a. new OCL

Table 2 : 25 kV - 50 Hz systems on ČD (Czech Republic)

Line characteristics			OCL	Feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section $[mm^2]$	n°	chemical composition and section $[mm^2]$	n°	chemical composition and section $[mm^2]$	tension [daN]		stitch wire Y/N	n°	chemical composition and section $[mm^2]$	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160	low		144			1	Bz 50		1 000	Y	1	Cu 100		1 000	S
160	medium		144			1	Bz 50		1 000	Y	1	Cu 100		1 000	S
200	high		264	1	Cu 120 [a]	1	Bz 50		1 000	Y	1	Cu 100		1 000	S

Equivalent Bz 50 $\approx$ 44 mm^2 Cu (1 mm^2 Bz 50 $\approx$ 0,88 mm^2 Cu)

a. new OCL

Table 3 : 15 kV - 16 2/3 Hz systems on CFF-FFS-SBB (Switzerland)

Line characteristics			**OCL**	**Feeder**		**Catenaries**					**Contact wires**				**Notes**
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160	medium	> 200	122			1	St Cu 50	600		N	1	Cu 107		850	N60
100	medium	> 200	202			1	Cu 95		800	N	1	Cu 107		800	RFL100
160	medium	> 200	192			1	St Cu 92		1 000	N	1	Cu 107		1 000	RFL125
180	medium	> 200	192			1	St Cu 92		1 200	Y	1	Cu 107		1 000	RFL140
200	high	> 400	192			1	St Cu 92		1 200	Y	1	Cu 107		1 200	RFL160
250	high	> 400	350	1	Cu 150	1	St Cu 102		1 350	Y	1	Cu 150		1 800	RFL250

Equivalent St Cu 50 ≈ 15 mm^2 Cu (1 mm^2 St Cu 50 ≈ 0,31 mm^2 Cu)
Equivalent St Cu 92 ≈ 85 mm^2 Cu (1 mm^2 St Cu 92 ≈ 0,92 mm^2 Cu)
Equivalent St Cu 102 ≈ 50 mm^2 Cu (1 mm^2 St Cu 102 ≈ 0,49 mm^2 Cu)

Table 4 : 15 kV - 16 2/3 Hz systems on DB-Netz (Germany)

Line characteristics			**OCL**	**Feeder**		**Catenaries**					**Contact wires**				**Notes**
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160			144			1	Bz II 50		1 000	Y	1	Ri 100 Cu		1 000	Re 160
200			144			1	Bz II 50		1 000	Y	1	Ri 100 Cu		1 000	Re 200
230			108,3			1	Bz II 50		1 000	Y	1	Rim 100 Cu Mg 0,5		1 500	Re 230mod
230			164			1	Bz II 50		1 000	Y	1	RiS 120 Cu Ag 0,1		1 500	Re 230mod
250			173,2	1	240 mm^2 Alu	1	Bz II 70		1 500	Y	1	RiS 120 Cu Ag 0,1		1 500	Re 250
330			277,2	1	240 mm^2 Alu	1	Bz II 120		2 100	Y	1	Rim 120 Cu Mg 0,5		2 700	Re 330
330			277,2	1	240 mm^2 Alu	1	Bz II 120		2 100	Y	1	Rim 120 Cu Mg 0,5		2 700	SICAT H 1.0

Equivalent Bz II 50 ≈ 44 mm^2 Cu (1 mm^2 Bz II 50 ≈ 0,88 mm^2 Cu) I_{max} = 200 A
Equivalent Rim 100 ≈ 64,3 mm^2 Cu (1 mm^2 Rim (Cu Mg 0,5) ≈ 0,64 mm^2 Cu)
Equivalent Rim 120 ≈ 77,1 mm^2 Cu
Equivalent Alu 240 ≈ 150 mm^2 Cu

Table 5 : 15 kV - 16 2/3 Hz systems on ÖBB (Austria)

Line characteristics			OCL	Feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
80	low		100			1	Stainless steel 40		1 035		1	Cu Ag 100		1 035	1.1
120	low		100			1	Stainless steel 40		990		1	Cu Ag 100		1 080	1.2
	medium		170	1	Al 260	1	Cu alloyed 70		990		1	Cu Ag 100		1 080	
	high		190	1	Al 260	1	Cu alloyed 70		990		1	Cu Ag 120		1 170	
160	medium		170	1	Al 260	1	Cu alloyed 70		990	Y	1	Cu Ag 100		1 080	1.3
	high		190	1	Al 260	1	Cu alloyed 70		990	Y	1	Cu Ag 120		1 170	
250	high		190	1	Al 260	1	Cu alloyed 70		1 080	Y	1	Cu Ag 120		1 530	2.1

Table 6 : 3 kV DC systems on PKP (Poland)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
100	low	< 50	170			1	Cu 70		950	N	1	Cu 100		953	C70-C
	low	< 50	320 [a]			1	Cu 120		1 373	Y	2	Cu 100		2 x 717	YC120-2C
160	medium	50 ÷ 100	295			1	Cu 95		1 216	Y	2	Cu 100		2 x 980	YpC95-2C
	high	> 100	320			1	Cu 120		1 428	Y	2	Cu 100		2 x 980	YpC120-2C
	medium	50 ÷ 100	440 [a]			2	Cu 120		2 x 1 609	Y	2	Cu 100		2 x 700	2C120-2C
200 [b]	high	> 100	440			2	Cu 120		2 x 1 588	Y	2	Cu 100		2 x 953	2C120-2C-1

[a] the values for OCL sections are required because of heavy freight trains

[b] no approved regulations - an experimental line

Table 7 : 3 kV DC systems on ADIF (Spain)

Line characteristics			**OCL**	**Reinforcing feeder**		**Catenaries**					**Contact wires**				**Notes**
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
120			367			1	Cu-ETP 153	980		N	2	Cu-ETP 107	882		CR 120
160			367			1	Cu-ETP 153		1 361	N	2	Cu-ETP 107		980	CR 160
200			638	1	Cu 153	1	Cu-ETP 185		2 499	N	2	Cu-ETP 150		1 837	CR 220
220			711	1	Cu 225	1	Cu-ETP 185		2 499	N	2	Cu-ETP 150		1 837	CR 220

Table 8 : 25 kV - 50 Hz systems on ADIF (Spain)

Line characteristics			**OCL**	**Reinforcing feeder**		**Catenaries**					**Contact wires**				**Notes**
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
300	low	25-50	165			1	Bz II 70	1 500		Y	1	Cu-Ag 0,1 120		1 500	Re 250

Table 9 : 3 kV DC systems on RFI (Italy)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day [a]						fix	automatic				fix	automatic	
150	low	< 50	320			1	Cu 120	1 075			2	Cu 100		2 x 750	FF1
200	low	< 50	320			1	Cu 120		1 375		2	Cu 100		2 x 1 000	FR1
	medium	100 ÷ 200	440			2	Cu 120		1 125		2	Cu 100		2 x 1 000	FR2
	high	> 200	610			2	Cu 155		1 000		2	Cu 150		2 x 1 125	FR4
250	medium	100 ÷ 200	540			2	Cu 120		1 500		2	Cu 150		2 x 1 875	FR7
	high	> 200	610			2	Cu 155		1 875		2	Cu 150		2 x 1 500	FR5

a. in Italy, on DC network: 1 train = 1 pantograph

Table 10 : 25 kV - 50 Hz systems on RFI (Italy)

Line characteristics			OCL	Feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
300	high	> 200	270			1	Cu 120		1 625		1	Cu 150		2 000	FR6

Table 11 : 3 kV DC systems on INFRABEL (Belgium)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
90			171			1	Cd-Bz 94	1 000		N	1	Cu E 107 [a]		1 000	S1
90			278			1	Cd-Bz 94	1 400		N	2	Cu E 107 [a]		2 x 1 000	S2-S3
140			342			2	CdBz 94 [b] CdCu 72 [c]	1 375 [b] 544 [c]		N	2	Cu E 107 [a]		2 x 1 000	CCa
160			372			2	CdBz 94 [b] CdCu 104 [c]	1 485 [b] 775 [c]		N	2	Cu E 107 [a]		2 x 1 000	CC
160			570	1	Al 366	2	CdBz 94 [b] CdCu 104 [c]	1 485 [b] 775 [c]		N	2	Cu E 107 [a]		2 x 1 000	CC with feeder
160			278			1	Cd-Bz 94		1 360	N	2	Cu E 107 [a]		2 x 1 040	R3-107
160			476	1	Al 366	1	Cd-Bz 94		1 360	N	2	Cu E 107 [a]		2 x 1 040	R3-107 with feeder
200			304			1	Cd-Bz 94		1 300	N	2	Cu Ag 120		2 x 1 500	R3-120
200			502	1	Al 366	1	Cd-Bz 94		1 300	N	2	Cu Ag 120		2 x 1 500	R3-120 with feeder
220			364			1	Cd-Bz 94		1 300	N	2	Cu Ag 150		2 x 2 000	R3-150
220			562	1	Al 366	1	Cd-Bz 94		1 300	N	2	Cu Ag 150		2 x 2 000	R3-150 with feeder

Equivalent Al 366 ≈ 198 mm^2 Cu (1 mm^2 Al ≈ 0,54 mm^2 Cu)
Equivalent Cd-Bz 94 ≈ 64 mm^2 Cu (1 mm^2 Cd-Bz ≈ 0,68 mm^2 Cu)
Equivalent CdCu 72 ≈ 64 mm^2 Cu (1 mm^2 CdCu ≈ 0,89 mm^2 Cu)
Equivalent CdCu 104 ≈ 94 mm^2 Cu (1 mm^2 CdCu ≈ 0,90 mm^2 Cu)
Equivalent Cu Ag 107 ≈ 107 mm^2 Cu (1 mm^2 Cu Ag ≈ 1 mm^2 Cu)

a. renewals with Cu Ag 107
b. Main catenary
c. Auxiliary catenary

Table 12 : 25 kV - 50 Hz systems on INFRABEL (Belgium)

Line characteristics			OCL	Negative feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
120			151		Al 228	1	Bz Sn 65		1 200	N	1	Cu E 107		1 200	R1 120
300			194		Al 288	1	Bz 65		1 400	N	1	Cu Ag 150		2 000	R1 300
350			160		Al 288	1	Cu Mg 94		2 000	N	1	Cu Mg 150		3 000	R1 350r

Equivalent Bz Sn 65 ≈ 44 mm^2 Cu (1 mm^2 Bz Sn ≈ 0,68 mm^2 Cu)
Equivalent Bz 65 ≈ 44 mm^2 Cu (1 mm^2 Bz ≈ 0,68 mm^2 Cu)
Equivalent CuMg 150 ≈ 64 mm^2 Cu (1 mm^2 CuMg ≈ 0,64 mm^2 Cu)

Table 13 : 1,5 kV DC systems on SNCF/RFF (France)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160			404	0		2	Main Al Ac 227 Auxiliary Al Ac 178	1 500 800		N	2	Cu 107		2 x 1 250	CNAlCu
			516	1	Al Ac 227										
			628	2	Al Ac 227										
			546	1	Al Ac 288										
			688	2	Al Ac 288										
220			477	0		2	Main Bz (37 %) 116 Auxiliary Cu 143	2 300 810		N	2	Cu 150		2 x 1 750	CRCu
			619	1	Cu 145										
			761	2	Cu 145										
			733	1	Cu 262										
			989	2	Cu 262										
			1 245	3	Cu 262										
			479	0		2	Main Bz (72 %) 116 Auxiliary Cu 104	1 820 590		N	2	Cu 150		2 x 1 750	CNRCu
			621	1	Cu 145										
			768	2	Cu 145										
			735	1	Cu 262										
			991	2	Cu 262										
			1 247	3	Cu 262										
			395	0		2	Main Bz (72 %) 116 Auxiliary Cu 104	1 820 590		N	2	Cu 107		2 x 1 250	CNCu
			537	1	Cu 145										
			679	2	Cu 145										
			651	1	Cu 262										
			907	2	Cu 262										
			1 163	3	Cu 262										
270			680	1	Cu 262	1	Bz (72 %) 181		2 500	N	2	Cu 150		2 x 2 000	CSRCu TGV A

Equivalent Al Ac 227 = 112 mm^2 Cu (1 mm^2 Al Ac = 0,493 mm^2 Cu)
Equivalent Al Ac 288 = 142 mm^2 Cu (1 mm^2 Al Ac = 0,493 mm^2 Cu)
Equivalent Al Ac 178 = 82 mm^2 Cu (1 mm^2 Al Ac = 0,46 mm^2 Cu)
Equivalent Bz (37 %) 116 = 43 mm^2 Cu (1 mm^2 Bz (37 %) = 0,37 mm^2 Cu)
Equivalent Bz (72 %) 116 = 83 mm^2 Cu (1 mm^2 Bz (72 %) = 0,71 mm^2 Cu)
Equivalent Bz (72%) 181 = 130 mm^2 Cu (1 mm^2 Bz (72 %) = 0,72 mm^2 Cu)

Table 14 : 25 kV - 50 Hz systems on SNCF/RFF (France)

Line characteristics			**OCL**	**Feeder**		**Catenaries**					**Contact wires**				**Notes**
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
140			126			1	Bz 35		700	N	1	Cu 107		1 000	7/10 kN
160			144			1	Bz 65		850	Y	1	Cu 107		1 150	8,5/ 11,5 kN
160			144			1	Bz 65		1 000	N	1	Cu 107		1 000	10/10 kN
220			144		(- feeder) Al Ac 288	1	Bz 65		1 200	N	1	Cu 107		1 200	12/12 kN
270			157		(- feeder) Al Ac 288	1	Bz 65		1 400	Y	1	Cu 120		1 500	14/15 kN
300			186		(- feeder) Al Ac 288	1	Bz 65		1 400	N	1	Cu 150		2 000	14/20 kN
350			203		(- feeder) Al Ac 288	1	Bz (72 %) 116		2 000	N	1	Cu alloy 150		2 500	20/25 kN

Equivalent Bz 35 = 21 mm^2 Cu (1 mm^2 Bz 35 = 0,600 mm^2 Cu)
Equivalent Bz 65 = 39 mm^2 Cu (1 mm^2 Bz 65 = 0,600 mm^2 Cu)
Equivalent Bz (72 %) 116 = 83 mm^2 Cu (1 mm^2 Bz (72 %) = 0,37 mm^2 Cu)
Equivalent Cu Alloy 150 = 120 mm^2 Cu (1 mm^2 Cu Alloy = 0,800 mm^2 Cu)

Table 15 : 3 kV DC systems on ŽSR (Slovak Republic)

Line characteristics			OCL	Reinforcing feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160	low		270			1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	medium		412,2	1	Al Fe 240	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	high		554,4	2	Al Fe 240	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
160	medium		390	1	Cu 120 [a]	1	Cu 120		1 500	Y	1	Cu 150		1 500	J
	high		510	2	Cu 120 [a]	1	Cu 120		1 500	Y	1	Cu 150		1 500	J

Equivalent Al Fe 240 ≈ 142,2 mm^2 Cu (1 mm^2 Al Fe 240 ≈ 0,59 mm^2 Cu)

[a] new OCL

Table 16 : 25 kV - 50 Hz systems on ŽSR (Slovak Republic)

Line characteristics			OCL	Feeder		Catenaries					Contact wires				Notes
maximum speed [km/h]	traffic density		total equivalent copper section [mm^2]	n°	chemical composition and section [mm^2]	n°	chemical composition and section [mm^2]	tension [daN]		stitch wire Y/N	n°	chemical composition and section [mm^2]	tension [daN]		national code
	-	pantographs per day						fix	automatic				fix	automatic	
160	low		144			1	Bz 50		1 000	Y	1	Cu 100		1 000	S
160	medium		144			1	Bz 50		1 000	Y	1	Cu 100		1 000	S
200	high		264	1	Cu 120 [a]	1	Bz 50		1 000	Y	1	Cu 100		1 000	S

Equivalent Bz 50 ≈ 44 mm^2 Cu (1 mm^2 Bz 50 ≈ 0,88 mm^2 Cu)

[a] new OCL

Appendix C - Safety distances

On the basis of the recommendations given in point 8 - page 45 to minimise the risk of electrocution during works on the OCL or near live conductors and installations, the different IMs have produced the following synthesis of their rules concerning the minimum electrical protection distance.

The electrical safety distances (clearances) that are strictly defined for specialist rail personnel (OCL workers) working near live OCL depend above all on the rated voltage of the energy system adopted.

These are defined by laws, national standards, railway rules and recommendations. In some cases they are defined as a national interpretation of different international standards, but it would be advisable to draw up a European standard to develop common criteria for achieving the maximum safety during works on electrical installations.

The safety distances to be observed by specialised workers delimit the zone around live conductors that workers must never enter into during work with arms, body parts or tools.

IM	**Electric traction system**			
	1,5 kV DC	**3 kV DC**	**15 kV AC**	**25 kV AC**
SNCF/RFF	1 m [a]			1 m [a]
ADIF		1,12 m [b]		1,48 m [b]
FS-RFI		1 m [a]		1 m [a]
DB-Netz			1,5 m [b]	
INFRABEL		0,5 m [c]		0,7 m [c]
CFF/SBB/FFS			1,5 m [a]	
ČD		0,9 m [a]		0,9 m [a]
ŽSR		0,9 m [a]		0,9 m [a]
PKP		0,6 m [b]		

a. Derived from national law for railways.
b. Derived from national law.
c. Fixed by railway (adopting the philosophy from EN 50122-1). There are minimum distances (vertical and horizontal) to observe between standing surfaces and live parts.

Appendix D - Maintenance levels and frequency of activities

Point 5 - page 28 describes OCL maintenance levels with reference to performances expected for the relevant line categories, from A to E, depending on the line speed and traffic density.

This Appendix contains completed tables to provide an idea of the frequencies adopted for scheduled maintenance activities depending on the choices made by the relevant IMs.

The table matrix is an initial draft to summarise activities the frequency of which may determine the proportion of preventive maintenance carried out and which is useful to qualify the maintenance level.

The tables list in particular the main types of scheduled activities described in point 4 - page 18, such as:

- inspections and checks as shown in point 4.1 - page 20,
- verifications, checks and measurements as shown in point 4.2 - page 24,
- scheduled maintenance, as shown in point 4.3 - page 26.

The frequency of inspections and observation rounds carried out on foot, by trolley and by train is indicated based on the guidelines introduced in the relevant points 4.1.1 - page 20, 4.1.2, 4.1.3 - page 23. The additional frequency strictly required for some of the main observations that are considered more important than the others is indicated as well.

The frequency of recording runs for verifications, checks and measurements is also indicated together with the examinations described in points 4.2.1, 4.2.2 - page 25. In addition, to provide a maximum of information about the importance of geometrical, mechanical and electrical parameters describing the condition of OCL and the quality of pantograph/catenary interaction, the special frequencies adopted for measurements are indicated also. Any further verifications required by railways are indicated in the subsequent lines next to the heading "Special measurements".

In the group of lines reserved for "Scheduled maintenance", firstly the frequency adopted for the activities described in point 4.3 is indicated; subsequent lines are used to indicate the special frequency required by railways for carrying out particular activities considered more important than others.

The following abbreviations are used to indicate the frequencies adopted:

- D = day,
- W = week,
- M = month,
- Y = year.

Table 17 : Maintenance activities periodicity - INFRABEL (Belgium)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)		- **on foot (4.1.1)**		4Y	2Y	1Y	6M	2M
		- **by trolley (4.1.2)**		2Y	1Y	1Y	1Y	1Y
		- **by train (4.1.3)**		1Y	1Y	1Y	1Y	1Y
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances						
		automatic tensioners		2Y	1Y	1Y	6M	4M
		switches						
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges						
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)		- **recording runs (4.2.1)**		1Y	1Y	1Y	IY	IY
		- **examinations (4.2.2)**						
	Parameters	**Geometrical**	height (gradient and sag)	1Y	1Y	1Y	1Y	1Y
			stagger	1Y	1Y	1Y	1Y	1Y
			wear	4Y	3Y	2Y	1Y	1Y
		Mechanical	contact forces	1Y	1Y	1Y	1Y	1Y
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing					
			earth resistance					
Scheduled maintenance (4.3)		- **hard time maintenance (4.3)**		2Y	1Y	1Y	6M	4M
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices		2Y	1Y	1Y	6M	4M
		disconnectors		1Y	1Y	6M	6M	4M
		section insulators, air gaps		2Y	1Y	1Y	6M	4M
		OCL over switches		2Y	1Y	1Y	6M	4M

Table 18 : Maintenance activities periodicity - ČD (Czech Republic)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)		- **on foot (4.1.1)**			6M	6M		
		- **by trolley (4.1.2)**						
		- **by train (4.1.3)**			2Y	2Y		
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges			1M	1M		
		electric clearances			6M	6M		
		automatic tensioners			1Y [a]	1Y [a]		
		switches			1M	1M		
		overhead crossings						
		diodes or voltage limiters			1Y	1Y		
		overvoltage discharges			1Y	1Y		
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)		- **recording runs (4.2.1)**			2Y	2Y		
		- **examinations (4.2.2)**						
	Parameters	**Geometrical**	height (gradient and sag)		6M	6M		
			stagger		6M	6M		
			wear					
		Mechanical	contact forces		6M	6M		
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing		6M	6M		
			earth resistance		1Y	1Y		
Scheduled maintenance (4.3)		- **hard time maintenance (4.3)**			3/6Y [b]	3/6Y [b]		
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors			1Y	1Y		
		section insulators, air gaps						
		OCL over switches						

a. Checking depends on the weather (hot days - daily)

b. 3Y-electric connections, line arresters, crossing OCL above switches, markers, 6Y-bridging conductors, gaps, headspans and other components.

Table 19 : Maintenance activities periodicity - PKP (Poland)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	- **on foot (4.1.1)**			8/12W	8W	4W	[a]	
	- **by trolley (4.1.2)**							
	- **by train (4.1.3)**			1Y	1Y	6M	[a]	
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances						
		automatic tensioners						
		switches						
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges						
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)	- **recording runs (4.2.1)**			1Y	1Y	6M	[a]	
	- **examinations (4.2.2)**							
	Parameters	**Geometrical**	height (gradient and sag)	1Y	1Y	6M	[a]	
			stagger	1Y	1Y	6M	[a]	
			wear	[b]	[b]	[b]		
		Mechanical	contact forces					
		Electrical	voltage					
			current					
			number of arcs	1Y	1Y	6M	[a]	
	Special measurements		geometry over points and crossing					
			earth resistance					
Scheduled maintenance (4.3)	- **hard time maintenance (4.3)**			2Y	1,5Y	1Y	[a]	
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

a. No approved procedures - an experimental line.

b. The schedule for subsequent measurements depends on results (actual wear).

Table 20 : Maintenance activities periodicity - DB-Netz (Germany)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	- **on foot (4.1.1)**			2Y	2Y	6M	6M	6M
	- **by trolley (4.1.2)**					1Y	6M	6M
	- **by train (4.1.3)**							
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances		2Y	2Y	2Y	2Y	2Y
		automatic tensioners		2Y	2Y	6M	6M	6M
		switches						
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges						
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)	- **recording runs (4.2.1)**					6M	6M	6M
	- **examinations (4.2.2)**			10Y	7Y	6Y	6Y	4Y
	Parameters	**Geometrical**	height (gradient and sag)	2Y	2Y	2Y	2Y	2Y
			stagger		2Y	6M	6M	6M
			wear	7Y	6Y	5Y	4Y	4Y
		Mechanical	contact forces		2Y	2Y	6M	6M
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing		1Y	6M	6M	6M
			earth resistance					
Scheduled maintenance (4.3)	- **hard time maintenance (4.3)**							
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

Table 21 : Maintenance activities periodicity - SNCF/RFF (France)

Scheduled Activities 1,5 kV				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	- **on foot (4.1.1)**			4/10W	4/8W	3/6W	3/5W	
	- **by trolley (4.1.2)**			2Y	1Y	6M	4/6M	
	- **by train (4.1.3)**							
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances						
		automatic tensioners						
		switches						
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges						
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)	- **recording runs (4.2.1)**			2/4Y	1/2Y	6M/1Y	6M/1Y	
	- **examinations (4.2.2)**							
	Parameters	**Geometrical**	height (gradient and sag)	4Y	2Y	1Y	1Y	
			stagger	4Y	2Y	1Y	1Y	
			wear	4Y	2Y	1Y	1Y	
		Mechanical	contact forces					
		Electrical	voltage	2Y	1Y	6M	6M	
			current	2Y	1Y	6M	6M	
			number of arcs	2Y	1Y	6M	6M	
	Special measurements		geometry over points and crossing					
			earth resistance	2/3Y	2/3Y	2/3Y	2/3Y	
Scheduled maintenance (4.3)	- **hard time maintenance (4.3)**			5/9Y	4/7Y	4/6Y	4/6Y	
	Special activities	cleaning insulators						
		lubrication of contact wire		3/6M	2/4M	1/2M	2/4W	
		automatic tensioning devices		3/4Y	3/4Y	3/4Y	3/4Y	
		disconnectors		3/4Y	3/4Y	3/4Y	3/4Y	
		section insulators, air gaps		3Y	2/3Y	1Y	1Y	
		OCL over switches		3Y	2/3Y	2Y	1Y	

Table 22 : Maintenance activities periodicity - SNCF/RFF (France)

Scheduled Activities 25 kV				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	- **on foot (4.1.1)**			6/10W	4/8W	3/6W	2/5W	3/6W
	- **by trolley (4.1.2)**			2Y	2Y	1Y	6M	4/6W
	- **by train (4.1.3)**			2Y	2Y	1Y	6M	2W
	Main components for observation		cantilevers					
			insulators					
			insulators with severe pollution					
			section insulators					
			gauges					
			electric clearances					
			automatic tensioners					
			switches					
			overhead crossings					
			diodes or voltage limiters					
			overvoltage discharges					
			switch disconnectors					
			transformers					
Verifications, checks and measurements (4.2)	- **recording runs (4.2.1)**			2/4Y	1/4Y	1/2Y	6M/1Y	1Y
	- **examinations (4.2.2)**							
	Parameters	**Geometrical**	height (gradient and sag)	4Y	4Y	2Y	1Y	1Y
			stagger	4Y	4Y	2Y	1Y	1Y
			wear	4Y	4Y	2Y	1Y	1Y
		Mechanical	contact forces					
		Electrical	voltage	2Y	1Y	1Y	6M	
			current	2Y	1Y	1Y	6M	
			number of arcs	2Y	1Y	1Y	6M	
	Special measurements		geometry over points and crossing					
			earth resistance	2/3Y	2/3Y	2/3Y	2/3Y	2/3Y
Scheduled maintenance (4.3)	- **hard time maintenance (4.3)**			6/9Y	5/8Y	4/7Y	4/6Y	4/6Y
	Special activities		cleaning insulators	[a]	[a]	[a]	[a]	[a]
			lubrication of contact wire					
			automatic tensioning devices	3/4Y	3/4Y	3/4Y	3/4Y	3/4Y
			disconnectors	3/4Y	3/4Y	3/4Y	3/4Y	3/4Y
			section insulators, air gaps	4Y	3Y	2/3Y	1/2Y	1/2Y
			OCL over switches	4Y	3Y	2/3Y	1/2Y	1/2Y

a. only with industrial or maritime pollution.

Table 23 : Maintenance activities periodicity - ADIF (Spain)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	**- on foot (4.1.1)**							
	- by trolley (4.1.2)							
	- by train (4.1.3)							
	Main components for observation	cantilevers				1Y	1Y	1Y
		insulators				1Y	1Y	1Y
		insulators with severe pollution				6M	6M	6M
		section insulators				6M	6M	6M
		gauges				1Y	1Y	1Y
		electric clearances				1Y	1Y	1Y
		automatic tensioners				1Y	1Y	1Y
		switches				6M	6M	6M
		overhead crossings						
		diodes or voltage limiters				1Y	1Y	1Y
		overvoltage discharges				1Y	1Y	1Y
		switch disconnectors				1Y	1Y	1Y
		transformers				1Y	1Y	1Y
Verifications, checks and measurements (4.2)	**- recording runs (4.2.1)**							
	- examinations (4.2.2)							
	Parameters	**Geometrical**	height (gradient and sag)			1Y	1Y	6M
			stagger			1Y	1Y	6M
			wear			1Y	1Y	6M
		Mechanical	contact forces			1Y	1Y	6M
		Electrical	voltage					
			current					
			number of arcs			1Y	1Y	
	Special measurements		geometry over points and crossing					
			earth resistance					
Scheduled maintenance (4.3)	**- hard time maintenance (4.3)**							
	Special activities	cleaning insulators						1Y
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

Table 24 : Maintenance activities periodicity - RFI (Italy)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	**- on foot (4.1.1)**			12M	8M	6M	4M	4M
	- by trolley (4.1.2)			1M	1M	1M	1M	1M
	- by train (4.1.3)			2M	2M	2M	2M	2M
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances						
		automatic tensioners						
		switches						
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges						
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)	**- recording runs (4.2.1)**			6M	4M	3M	1M	2W
	- examinations (4.2.2)			4Y	2Y	2Y	1Y	6M
	Parameters	**Geometrical**	height (gradient and sag)					
			stagger					
			wear					
		Mechanical	contact forces					
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing					
			earth resistance					
Scheduled maintenance (4.3)	**- hard time maintenance (4.3)**			4Y	2Y	2Y	1Y	1Y
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

Table 25 : Maintenance activities periodicity - ŽSR (Slovak Republic)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)	- **on foot (4.1.1)**			6M	6M	2M		
	- **by trolley (4.1.2)**							
	- **by train (4.1.3)**					1Y		
	Main components for observation	cantilevers						
		insulators						
		insulators with severe pollution						
		section insulators						
		gauges						
		electric clearances		1Y	1Y	1Y		
		automatic tensioners		1Y	1Y	1Y		
		switches		1Y	1Y	1Y		
		overhead crossings						
		diodes or voltage limiters		1M	1M	1M		
		overvoltage discharges		2Y	2Y	1Y		
		switch disconnectors						
		transformers						
Verifications, checks and measurements (4.2)	- **recording runs (4.2.1)**				2Y	1Y		
	- **examinations (4.2.2)**			4Y	2Y	2Y		
	Parameters	**Geometrical**	height (gradient and sag)	6M	6M	1M		
			stagger	6M	6M	1M		
			wear	4Y	4Y	3Y		
		Mechanical	contact forces			1Y		
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing	6M	6M	3M		
			earth resistance					
Scheduled maintenance (4.3)	- **hard time maintenance (4.3)**			4Y	2Y	2Y		
	Special activities	cleaning insulators		1Y	1Y	1Y		
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

Table 26 : Maintenance activities periodicity - SBB (Switzerland)

Scheduled Activities				**Maintenance level line categories**				
				A	**B**	**C**	**D**	**E**
Inspections and observation (4.1)		- **on foot (4.1.1)**		1Y	1Y	1Y	1Y	
		- **by trolley (4.1.2)**						
		- **by train (4.1.3)**			2Y	1Y	2W	
	Main components for observation	cantilevers		1Y	1Y	1Y	1Y	
		insulators						
		insulators with severe pollution		1Y	1Y	1Y	1Y	
		section insulators						
		gauges		1Y	2Y	1Y	2W	
		electric clearances		1Y	2Y	1Y	2W	
		automatic tensioners		1Y	1Y	1Y	1Y	
		switches		1Y	1Y	1Y	1Y	
		overhead crossings						
		diodes or voltage limiters						
		overvoltage discharges		1Y	1Y	1Y	1Y	
		switch disconnectors		1Y	1Y	1Y	1Y	
		transformers		1Y	1Y	1Y	1Y	
Verifications, checks and measurements (4.2)		- **recording runs (4.2.1)**			2Y	1Y	2W	
		- **examinations (4.2.2)**		4Y	2Y	2Y	1Y	
	Parameters	**Geometrical**	height (gradient and sag)		2Y	1Y	2W	
			stagger		2Y	1Y	2W	
			wear		2Y	1Y	3M	
		Mechanical	contact forces		2Y	1Y	2W	
		Electrical	voltage					
			current					
			number of arcs					
	Special measurements		geometry over points and crossing		1Y	1Y	1Y	
			earth resistance					
Scheduled maintenance (4.3)		- **hard time maintenance (4.3)**		4Y	2Y	2Y	1Y	
	Special activities	cleaning insulators						
		lubrication of contact wire						
		automatic tensioning devices						
		disconnectors						
		section insulators, air gaps						
		OCL over switches						

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Warning

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