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Diagnosis of the OCL conditions

Diagnostic de l'état de la caténaire

Diagnose des Oberleitungszustands



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Summary

This document was prepared, within the UIC Infrastructure Forum by the Energy and Electric Traction experts of the Technology Support Group, to provide all the railways with guidelines for testing, monitoring and diagnosing the OCL conditions and performance, on the basis of uniform criteria and common objectives.

All the needs regarding the checking and testing of the OCL characteristics, depending upon the required or expected performance, were investigated by analysing the relevant context and the objectives to be attained.

In particular the main parameters that characterise the behaviour of the OCL in static or dynamic conditions were enhanced, together with the methods to be applied, the procedures to be followed and the diagnostic systems to be adopted.

1 - General

1.1 - Scope

These guidelines relate to the need for periodical or continuous understanding of the OCL conditions with the relevant parameters to be measured, the analyses to be performed, the means and the diagnostic systems to be adopted.

The reference contexts and the objectives to be attained are integrated into the primary objective of checking, testing and monitoring the OCL lines, improving the reliability and the availability of the installations, supporting the maintenance interventions, reducing failures and bringing down the total costs of maintenance and management.

Lastly, the tests to be performed and the data in question cover not only the needs relating to behaviour conditions of the operating OCL but also the requirements regarding the putting into service of new lines or the certification of their interoperability performance.

1.2 - References

See Bibliographie - [page 65](#).

1.3 - Field of application

This leaflet sets out to diagnose the conditions of all overhead railway contact lines (OCL) supplied with either DC or AC current, under different traffic conditions, speeds, etc.

The leaflet can be applied in particular to the OCL 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 parameters to be measured or to the characteristics of the OCL to be checked but also to general information about the testing devices and procedures, methods, etc.

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.

Diagnosis

The art or act determining the nature of a fault from its symptoms.

Diagnostic testing

Test procedure carried out in order to make a diagnosis.

Technical diagnostics

The procedure of determining the technical condition of a device with defined accuracy and reliability.

Diagnostic system

Organized system consisting of the diagnostic means, device under test and staff: its function is to determine the technical condition of the device under test.

Diagnostic means

The set of technical (diagnostic) facilities, methods and procedures (e.g. software) that permits the performance of the analysis and the evaluation of the technical condition of the device under test¹.

Diagnostic signal

The signal which bears information on the technical condition of the device under test or its parts.

Diagnosing (diagnostic verification)

The set of works associated with the preparation of tests, their performance in a given order and the evaluation of the technical condition of the device under test.

Failure detection

Failure identification of the device based on the diagnostic signal values.

Failure location

The device failure location based on the diagnostic signal values.

Fault simulation

The method for discovering the reaction of the device in an artificial fault condition.

Measurement vehicle

Any facility in which the measurement unit is mounted and used for measurements.

1. Diagnostic means may be applied as part of a device or independently.

Maximum measurement speed

The maximum speed of the vehicle in which the measurement unit is mounted.

Mobile diagnostic system

The measuring devices or the diagnostic systems installed on board vehicles.

Measuring car

The measuring car is a special carriage, generally added to commercial trains, that makes it possible to check, monitor or control some important characteristics of the OCL. It has the advantage that it is possible to acquire a great deal of data without the necessity of track possession.

Diagnostic train

The diagnostic train is a special train with the sole purpose of checking the characteristics and the performance of the rail lines (infrastructure and installations).

Fixed diagnostic system

The measuring or diagnostic systems installed within substations or along the line.

Measurement with contact

The measurement method in which the device under test (OCL) is mechanically connected to a reading mechanism.

Measurement without contact

The measurement method in which the device under test (OCL) is mechanically isolated from the reading mechanism, but is isolated through other method, e.g. through air, and the connection between the reading mechanism and the device under test is made optically, for example, or through an electric or magnetic field.

Measurement under voltage

Measurement in which the device under test is tested under the catenary's voltage.

Measurement without voltage

Measurement in which the device under test is tested not under the catenary's voltage.

Static measurement

Measurement conditions in which neither the device under test nor the measurement unit changes its position during testing.

Mobile measurement

Measurement conditions in which both the device under test and the measurement unit change their position during testing.

Thermovision (Thermography)

The diagnostic method based on contact-free measurement of temperature. It is based on the temperature distribution analysis of the item surface under diagnosis.

Diagnostic measured parameter OCL

The OCL parameter, the values of which are determined by measurement for diagnostic purposes.

Static parameter OCL

The parameter describing a conducting wire performance under static OCL conditions; it includes, in particular, OCL geometric parameters, for example: height, stagger, sag, etc.

Dynamic parameter OCL

The parameter describing conducting wire performance under dynamic OCL conditions; it includes, in particular, such parameters as contact force, arcs, etc.

Diagnostic calculated parameter

The diagnostic parameter value derived from a calculation using other measured or calculated parameters.

Diagnostic post-processed parameter OCL

The OCL parameter, the values of which shall be determined when the diagnostic measurement is performed.

Diagnostic auxiliary parameter

The parameter needed to measure and evaluate the OCL diagnostic parameters to be measured.

Geometrical parameter OCL

The parameter describing the OCL geometrical structure.

Mechanical parameter OCL

The parameter describing the OCL mechanical performance.

Electrical parameter OCL

The parameter describing the OCL electrical performance.

Height

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

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.

Sag

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

Gradient

Ratio of the difference in height of the overhead contact line above the rail level at two successive supports to the length of the span.

Uplift

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

Tension lengths

Length of overhead contact line between two anchoring points.

Span

The overhead contact line from one support or suspension point to the next.

Overlap span

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

Span length

Length of overhead contact line between two masts.

Arcs

Flow of current through an air gap between a contact strip and a contact wire usually indicated by the emission of intense light.

Forces between pantograph and OCL

Vertical force applied by the pantograph to the overhead contact line.

3 - Catenary diagnosis

In a modern railway it is increasingly important to develop and improve activities for checking, testing and monitoring the characteristics and performance of infrastructure and fixed installations to verify their quality of construction before they are put into service, and to continuously check that the reliability, availability and safety of the lines are maintained at the levels determined within the project or expected based upon real operating conditions.

For the energy subsystem in particular, it is crucial that the catenary performance and its behaviour under the pantograph forces, depending on the line speed, be verified.

3.1 - Resources

To pursue the aims assigned or expected, the railways have to provide means, equipment and diagnostic systems that are technological advanced in their hardware and software performance.

In fact, even though some parameters could be measured manually, it is becoming very important to acquire and promote the use of new means, both to improve productivity and to provide the maximum feedback for examining the data measured and analysing parameters and trends.

The development of catenary diagnosis requires the organisation and management of new kinds of resources, consisting of innovative technologies and experts in this field.

The following, in particular, could be foreseen:

- the introduction of means and devices for checking, testing and measuring the OCL characteristics;
- the adoption of diagnostic systems, to be installed along line or on board of trains or trolleys, for the automatic checking or monitoring of the OCL performance;
- an increase in the capability of software to study, analyse and compare data, functions and trends in different measurement situations or recording runs;
- the capability of diagnostic personnel to optimise the use of resources, to be employed for the needs of the whole network, to analyse the results and to elaborate upon data that has to be released in structured and scheduled ways for different objectives.

3.2 - Main goals and benefits

The development of OCL diagnosis represents a sort of revolution in the management of electric traction installations and the relevant resources, facilitating the passage from "time-based" to "condition-based" maintenance.

In particular, starting from a proper diagnosis of the catenary, it is possible to reach many important goals in the field of the electric installations, such as:

- optimisation of maintenance planning;
- steering and selecting of maintenance activities;

- support for the interventions to rectify failures that have occurred;
- guidance of maintenance personnel in the rectification of failures;
- organisation and use of track possessions with the maximum productivity on the part of the maintenance personnel;
- improvement of the reliability and the regularity of operating;
- focussing upon the main causes of poor functioning of the installations;
- tracking down the poor or missed performance of maintenance activities.

The use of diagnosis soon has a very positive effect upon the management of rail lines and the regularity of the train circulation, due to the:

- reduction in the number and severity of failures;
- reduction in the time spent rectifying failures;
- reduction in the need for track possessions;
- increase in the availability of the track.

General benefits could be appreciated, due to the contribution to the:

- increase in the regularity of circulation;
- assurance of safety of circulation;
- provision of margins for current absorption or speed increase;
- containment of maintenance costs;
- reduction of total costs.

4 - Parameters to be measured or calculated

To acquire and maintain an in-depth knowledge of the conditions and performance of the OCLs, it is important to introduce both the main parameters, that it is recommended be checked and measured, and the main functions and trends, that it is suggested be elaborated and analysed, referring to the operating condition and/or to the project data.

Some parameters, to be measured under static and/or dynamic conditions, are particularly significant and characterise the quality of construction and installation of the OCL and its behaviour during operation and in the interaction with pantographs.

All the relevant parameters can be grouped into three areas, depending upon the aspects to be verified:

- geometrical,
- electrical,
- mechanical.

4.1 - Geometrical parameters

First of all, the geometrical parameters allow us to understand the position of the OCL's wire conductors in relation to the track under static conditions. In particular, the **height** and the **stagger** of the contact wires characterise the so called "contact plane" for the running of the pantographs.

All the geometrical parameters have to be measured under static conditions, or "without contact", because only starting from these values can maintenance personnel plan and implement the corrective measures and verify the quality of results. Some of them could also be measured under dynamic condition for checking specific aspects of the OCL's behaviour under the forces exerted by pantographs.

Some diagnostic systems, so called "with contact" systems, can check the height and the stagger under the running of a special pantograph (generally adopted for measurements of electrical and mechanical parameters). In this case the data output is affected by dynamic conditions.

The tolerances admitted for the measures generally diminish as the performance expected for the OCL under test increases.

Some of the geometrical parameters, e.g. the height, are also influenced by external conditions, such as air temperature, and by the characteristics of the measuring systems adopted or of the vehicles on which the systems are installed.

In consequence, all the auxiliary data that can influence the measured values must be contemporaneously checked to ensure the correct analysis necessary for the diagnosis of the geometrical characteristics and performances of the OCL.

4.1.1 - Height

As is well known, the height of the contact wires in relation to the rail plane must be held as constant as possible in order to ensure the best possible interaction with the pantograph.

The height is generally measured **by an insulating device, at steady arm** and in the mid-span, but can be measured automatically by optical devices (without contact) installed on board trains, carriages and trolleys, with the advantage that checking takes place continuously.

If the automatic checks are performed by a measurement pantograph (with contact), the values checked have to be interpreted and adjusted by mathematic algorithms to extrapolate the corresponding values under static conditions.

4.1.2 - Stagger

The stagger indicates the displacement of the point of contact between the contact wires and the collector strips in relation to the centre of the track. Its value may not exceed the maximum permissible value to ensure that wear to the contact zones of the collector strips is as uniform as possible.

Stagger measurements are also generally performed manually, **at steady arm** and in the mid-span, but can be checked automatically by optical devices, together with the height.

Height and stagger are project parameters that characterise the OCL performances. They have to be measured to check correspondence with project requirements before new lines are put into service.

They obviously have to be measured **regularly** to guarantee that the expected characteristics of the OCLs are maintained during operation.

4.1.3 - Critical points (distances between earthed parts and other parts)

The OCL may have "critical points" along the lines, which should be periodically checked to prevent failures, due to the increased probability of changes in position in relation to tunnels ceiling or/and earthed parts of bridges, infrastructures, crossings and so on.

In this case, some geometric parameters that define the distance between live conductors and elements of the OCL and earthed parts and/or other conductors should be checked at specified intervals.

Other (unscheduled) measurements are required if visual inspections on foot or by train, raise doubts regarding the probability of electric discharges towards earthed parts or of mechanical interference involving OCL parts, components or elements in pantograph running.

4.1.4 - Wear

For maintenance it is important that the **wear** of the contact wires, generally indicated by the residual **thickness**, be measured.

The main aim is to plan maintenance measures such that the uniform wear of the contact wires is ensured until they are replaced.

Using modern technologies it is possible to measure the wear almost continuously. This also facilitates the prompt discovery of so-called "rigid points", where the wear could be rapidly increased.

4.1.5 - Sag and gradient

Some parameters are usually calculated by the elaboration of the height measures, such as the **sag** and the **gradient** of the contact wires alongside their length.

The maximum sag, generally calculated in the mid-span, may not exceed the permitted values for the OCL's performance in the project.

Likewise, the gradient, which specifies the height variation in relation to the spanned distance (dh/dx), has to be as low as possible.

These parameters give a good idea of the quality of the current collection, as the pantographs suffer the changes of height overcoming predetermined limits depending on their speed.

The *TSI* (see [Bibliography - page 65](#)), requiring a constant height for the OCL in high speed lines, reduces to zero the permitted sag and gradient values.

Particular attention has to be paid to the evaluation of the position of the conductors approaching or along the **overlap spans**.

4.1.6 - Longitudinal sizes

Other geometrical sizes (lengths or distances) must be considered for the optimum analysis of the trends for the above-mentioned parameters that are checked or calculated along the line, including the **tension lengths** and the **span lengths**.

These lengths, with the position of the poles and/or of the suspensions, are necessary to permit a complete investigation on the OCL layout and performance.

4.1.7 - Uplift

So-called "**uplift**" is a geometrical parameter relating to dynamic conditions that is of great importance for the quality of captation and the pantograph/catenary interaction. It indicates the difference between the height measured with pressure from the pantograph and the corresponding one measured in static conditions.

This parameter has to be correlated with the force exerted by the pantograph pushing against the contact wires, depending on train speed, wind and other conditions.

Its measurement, together with that of the forces, is generally performed in dynamic conditions, but it is important to plan apposite checks by suitably equipped trolleys in static conditions.

The trend of the uplift under a constant force has to be as constant as possible to characterize a good uniformity of elasticity (see [point 4.3.3 - page 16](#)) of the OCL.

Uplift could be measured along the line, in single sections, by special fixed posts able to detect this parameter whilst pantographs are running. As a consequence it could be possible to use the measurement system to request that trains to lower their pantographs when they seem to be broken or malfunctioning.

4.1.8 - Uplift uniformity

The difference between the maximum and the minimum uplift along the spans could be considered a very useful parameter for evaluating the quality of the OCL characteristics and of the catenary/pantograph interaction.

4.2 - Electrical parameters

The electrical characteristics of the energy subsystem and of the OCL performance can be only checked by "with contact" measures, using a specially equipped power pantograph or a measuring pantograph.

Generally it is possible to determine the condition of the OCL performance by the interpretation of the electrical phenomena that arise during the run, such as the generation of arcs between the contact wires and the pantograph strips.

Sometimes it is possible to detect oncoming failures and emerging damage by the automatic checking of the over-temperature of OCL components caused by current flow. Thermal imaging can be used as a diagnostic system to recognise the so called "hot spots".

4.2.1 - Voltage

The **voltage** of the OCL for every electric traction system can vary within the range set by the *EN 50163* (see Bibliography - page 65). The temporary value obviously depends on the substation's output voltage and on the load absorbed along the line.

The voltage at the feeding points (immediately outside the substations) is generally measured and recorded by the instruments installed within the substations.

The voltage at the pantograph is generally monitored, though with insufficient accuracy, on board the cabins of commercial trains.

Besides checking the voltage with optimum precision, the availability of a measuring pantograph on board a diagnostic train or a special measuring coach added to a commercial train, permits the tracking and recording of periods of sudden voltage drop due to loss of contact. This can represent one of the methods for demonstrating the quality of the interaction between catenary and pantograph.

4.2.2 - Current

As we know, the current collected, together with the line voltage, is usually checked on board the trains.

Accurate checks are possible by equipping the power pantograph of a diagnostic train with special systems able to measure and record the trend of these functions and to determine the generation of arcs and the corresponding voltage drops, which also demonstrate the so-called "losses of contact".

Other parameters of current are generally measured and recorded inside substations. Furthermore, if these parameters relate to the total load supplied by a branch of the OCL, their reading could be of interest in helping to discover some types of emerging failures caused by losses of insulation; if **low currents** are found to flow when there are no trains on the line this may indicate that an insulator is about to break.

4.2.3 - Losses of contact and arcs

As mentioned above, **loss of contact** between the pantograph and the contact wires can be demonstrated by a temporary interruption of current or a decrease in voltage.

Using special equipment installed on board diagnostic trains or measuring cars, it is possible to monitor the **arcs** and to measure their duration.

According to *EN 50317* (see Bibliography - page 65) an important parameter to be calculated is the **percentage of arcing** found using the formula:

$$NQ = (\Sigma t_{\text{arc}} / t_{\text{total}}) \times 100$$

where t_{arc} is the duration of an arc lasting longer than 5 ms and t_{total} is the measuring time for which current is greater than 30 % of the nominal current.

The result of the formula is strongly dependent upon the speed reached during the measurements.

In the new high speed line, according to *TSI and EN 50367* (see Bibliography - page 65), the maximum value of the NQ is 0,1 or 0,2, depending on the type of OCL line.

4.2.4 - Electric warming and thermal imaging

As we know, the flowing of the current, along the conductors of the OCL and through terminals, connections and clamps, produces warming and increases the temperature of the parts in question.

This phenomenon could be monitored by thermal imaging systems, with the aim of determining the so called "**hot spots**", that provide evidence of the increased electrical resistance of oxidized or loose contacts.

The thermal imaging systems are installed in special carriages, from which it is possible to focus upon the OCL and record the temperature reached.

For measurements to be of use, it is necessary for the OCL to be quite warm. This can be achieved by planning the circulation of the train with the test coach after having warmed the OCL using special devices or after a period of intense traffic.

This method of discovering emerging damages is particularly indicated more for DC voltage traction systems (1,5 and 3 kV), that require high levels of currents flowing along the lines, than for AC systems (15 or 25 kV) that need of low currents and produce limited over temperatures.

4.3 - Mechanical parameters

The mechanical performance of the OCL can only be dynamically checked "with contact" by a pantograph equipped for checking the quality of the catenary/pantograph interaction, by measuring the force of pressure against the contact wires.

Static measurements are required to measure the elasticity parameters and to test the OCL reaction under assigned forces at individual points.

4.3.1 - Forces

The forces exchanged between the pantograph and the OCL depend on the real pressure exerted by the pantograph, as in static conditions, and the added aerodynamic force exercised by the air and increasing with speed.

These forces are generally measured on board the diagnostic train, by an instrumented pantograph with special dynamometric cells. The total force exchanged between the pantograph strip and the contact wires is calculated as the sum of the elementary forces measured by the individual cells applied along the supports of the strip.

An elaboration system enables to calculate the average value of the force and the standard deviation.

In the new high speed lines, according to *TSI and EN 50367* (see Bibliography - page 65), the average value of the force (F_m), in relation to speed reached, has to follow the trends indicated by the curves reported in Figures 1 and 2 - page 15, respectively for AC and DC lines.

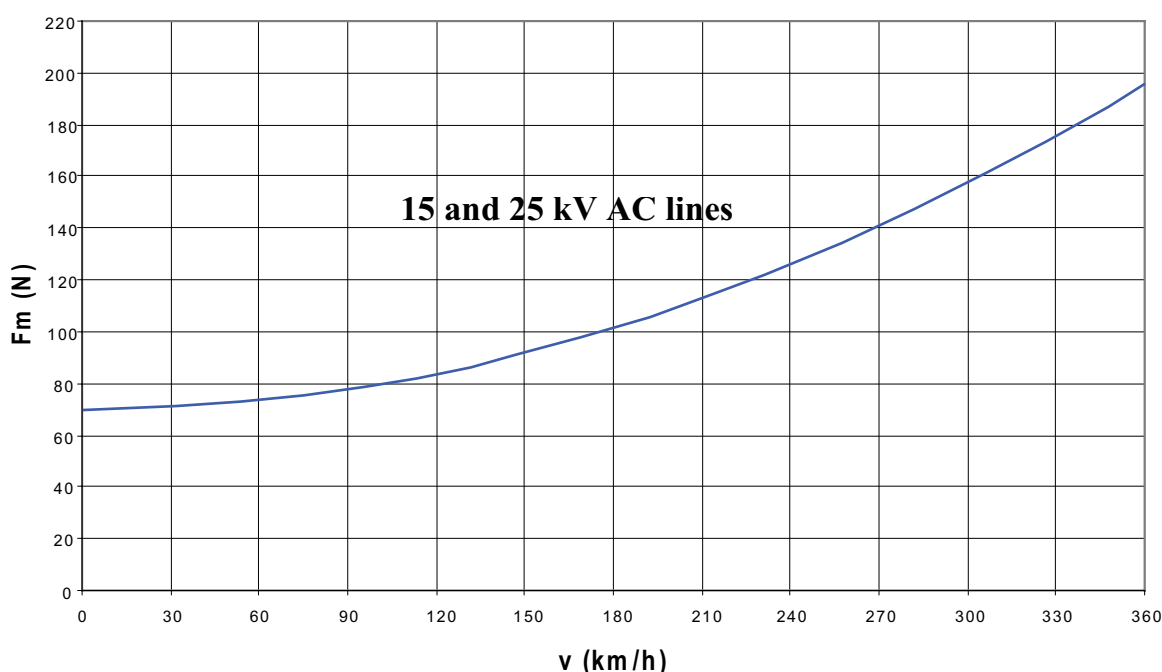


Fig. 1 - Trend expected for the average contact force (F_m) as a function of the running speed (v) for AC systems

In particular the target values of F_m (expressed in Newtons), are calculated using the following formulas:

- $F_m = 0,00097 \times v^2 + 70$ (for AC lines, see Fig. 1);
- $F_m = 0,00097 \times v^2 + 110$ (for 3 kV DC lines, see curve a of Fig. 2);
- $F_m = 0,00228 \times 10^{-4} \times v^2 + 90$ (for 1,5 kV DC lines, see curve b of Fig. 2),

where v is the value of the speed, to be indicated in km/h.

For the optimum interaction with the catenary, it is important that the force should be as constant as possible and continuously positive. This concept is also described by the generally adopted formula:

$$F_m - 3\sigma_{\max} > 0$$

In the new high speed line, according to *TSI and EN 50367* (see Bibliography - page 65), the standard deviation at the maximum speed ($\sigma_{\max}$) has to be in line with the following formula:

$$\sigma_{\max} \leq 0,3 \times F_m$$

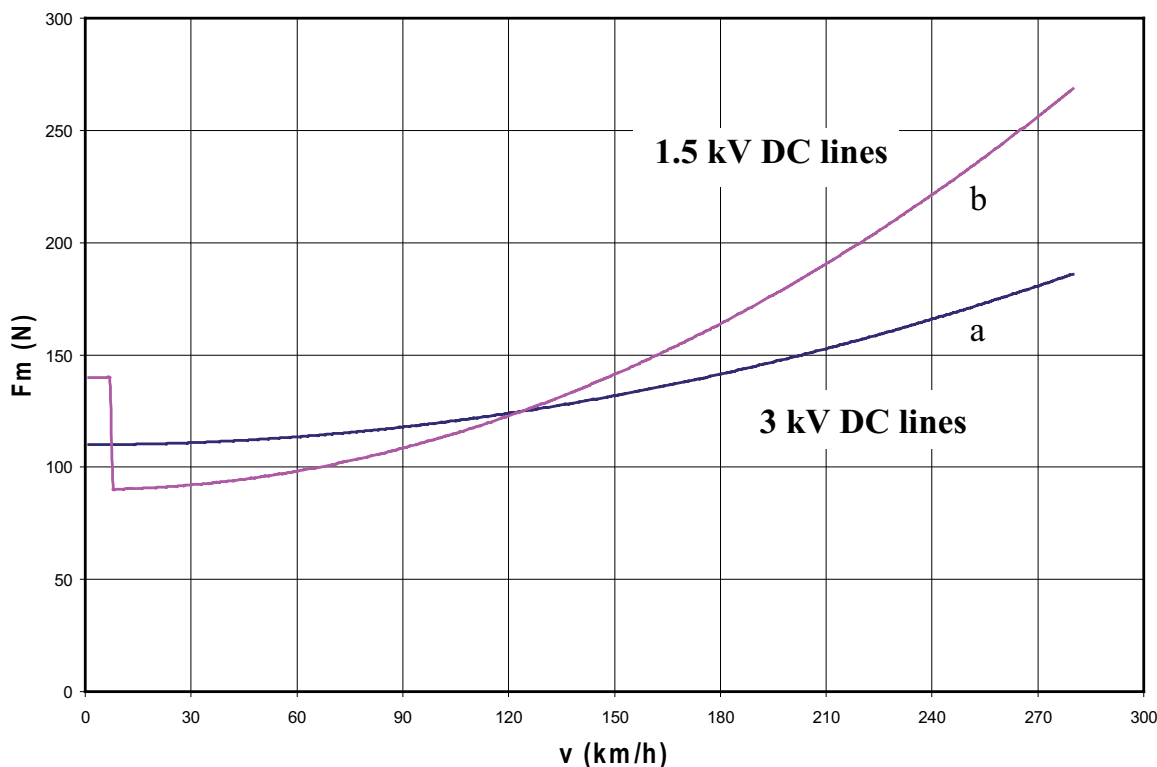


Fig. 2 - Trend expected for the average contact force (F_m) as a function of the running speed (v) for DC systems

In the case of trains with multiple pantographs operating simultaneously, the mean contact force F_m for any pantograph may not exceed the values indicated by the curves in the Fig. 1 - page 14 and 2.

4.3.2 - Elasticity

As a consequence of the forces exerted by the running pantographs, the contact wires are pushed upwards and the corresponding uplift (delta height between the dynamic and the static condition, see point 4.1.7 - page 11) may not exceed the limit permitted by the OCL characteristics, to avoid pantograph strips coming into contact with arms or other cantilever elements.

This dynamic behaviour of the OCL is strongly dependent upon its mechanical characteristics, such as elasticity, which could be verified by measuring the uplift along the line under assigned forces in static conditions.

The **elasticity** of the OCL, calculated point by point, is a parameter (expressed in mm/N) indicated by the ratio between the maximum uplift (measured in mm) and the force exerted (measured in N):

$$e = \Delta h / f$$

Elasticity should remain as constant as possible as line speed increases. It is a result of the OCL performance with particular reference to the tensioning forces exercised on the conductors through the tensioning devices.

For high-speed lines, elasticity calculated at the mid-span should be limited to values less than 0,5 mm/N.

4.3.3 - Elasticity uniformity

For the reasons mentioned above, to provide evidence of the OCL behaviour for the optimum quality of the catenary/pantograph interaction, a new parameter called **uniformity of elasticity** is generally calculated (see *TSI - Bibliography - page 65*), expressed as a percentage, and being the ratio of the difference between the maximum and the minimum elasticity and the sum of both:

$$u(\%) = (e_{\max} - e_{\min}) / (e_{\max} + e_{\min}) \times 100$$

where $e_{\max}$ and $e_{\min}$ are the maximum and minimum elasticity along a span.

For example, in the new high speed lines at 300 km/h without stitch wire, the TSI require that the u (%) may not exceed 40 %.

4.4 - Auxiliary data

For the analysis of the measures taken and the provision of objective data that is immediately useful for maintenance interventions and suitable for comparison or processing on any occasion, it may be necessary or opportune to also record some other parameters or situations related to the outside temperature and weather conditions, the operating conditions of the OCL, the behaviour of the vehicles used and the characteristics of the diagnostic systems employed.

Clearly, as all the OCL data measured or calculated have to be related to the checked location along the line, it is crucial that the exact starting point and the subsequent distance travelled are known. All the reference points encountered along the line such as tunnels, bridges, level crossings, singular points of the line and of the OCL also represent valuable data for the optimum analysis of the measurements performed.

Taking into account the above aims, the main auxiliary data to be checked or recorded are:

- the outside temperature;
- the weather conditions (sun, rain, wind, ice, fog, etc.);
- the speed and direction of the wind;
- the method of checking (static, dynamic, with or without contact, etc.);
- the characteristics of the observed line and of the existing infrastructures (curves, gradient, inclinations, presence of tunnels, bridges, level crossings, etc.);

- the characteristics and the operating conditions of the observed OCL (energised or not, presence of singular points, tensioning places, etc.);
- the characteristics and performance levels of the employed vehicle (speed, geometrical references, dynamic perturbation to the measures, etc.);
- the characteristics and the performance levels of the measurement devices or of the diagnostic systems (speed, tolerances, dynamic perturbation to the measures, etc.);
- the characteristics and the performance levels of the diagnostic fixed systems along the line (recording and monitoring instruments inside the substations, fixed stations for measuring of uplift and other parameters, etc.).

5 - Main objectives to be achieved

The parameters checked, the variables measured and the data calculated are analysed and post processed to obtain quality indices, curves and trends, which will be introduced further on.

The main objectives to be pursued through the analysis of the data collected relate to the following strategic aspects:

- the capacity to develop fault prevention and fault finding;
- the necessity of assisting the planning of maintenance works;
- the necessity of having objective tests for controlling the quality of the interaction between catenary and pantograph and of the current collection;
- the necessity of improving safety conditions.

5.1 - Fault prevention and fault finding

The capacity to use the diagnosis to prevent faults is the first important item to be developed.

Fault prevention has to be quite fast due to the seriousness of the danger emerging in an initial diagnosis.

For this reason, the initial outcome of the diagnosis process, even if it is approximate as well as quick, must be immediately put at the disposal of the maintenance personnel to help them intervene in an appropriate manner and promptly remove the potential causes of a failure.

5.2 - Maintenance planning

The art of maintenance organisation, management and planning can be increasingly assisted by using the diagnosis in an optimum and easily readable manner to further the maintenance objectives.

Starting with a well organised package of diagnostic data, it is possible to perform the planning, optimise the maintenance interventions, schedule all the activities to be performed, improve the reliability of the OCL and reduce maintenance costs.

5.3 - Quality of OCL - pantograph interaction

The necessity of testing the OCLs, for the ad hoc checking of their characteristics and performance, is another objective of the diagnostic systems.

This is particularly important for checking the characteristics of the the OCL and validating its conformity with TSI requirements before putting it into service, especially in high speed lines.

The employment of the most sophisticated and technologically advanced diagnostic systems, installed in special trains, permit the assessment with the maximum accuracy of both the *quality of current collection and the quality of the catenary/ pantograph interaction*.