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SIST EN 50318:2019

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Železniške naprave - Sistemi tokovnega odjema - Veljavnost simuliranja medsebojnih dinamičnih vplivov med tokovnim odjemnikom in kontaktnim vodnikom

Railway applications - Current collection systems - Validation of simulation of the dynamic interaction between pantograph and overhead contact line

Bahnanwendungen - Stromabnahmesysteme - Validierung von Simulationssystemen für das dynamische Zusammenwirken zwischen Dachstromabnehmer und Oberleitung

Applications ferroviaires - Systèmes de captage de courant - Validation des simulations de l'interaction dynamique entre le pantographe et la caténaire

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Railway applications - Current collection systems - Validation of simulation of the dynamic interaction between pantograph and overhead contact line

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European foreword

This document (EN 50318:2018) has been prepared by CLC/SC 9XC "Electric supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)" of CLC/TC 9X "Electrical and electronic applications for railways".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2019-12-07
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2021-12-07

This document supersedes EN 50318:2002.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

EN 50318:2018 includes the following significant technical changes with respect to EN 50318:2002:

— additional definitions for new used terms are included (Clause 3);

— the validation process is improved (Clause 5);

— a validation process for pantograph models is included (Clause 6);

— data requirements for overhead contact line modelling are improved (7.2);

— requirements for static checks for the overhead contact line are included (7.3);

— mathematical parameters to describe deviation from Gaussian distribution added to the required output (Clause 9);

— the validation with measured values is improved (Clause 10);

— measured data from line tests are included for three main types of overhead contact lines in Annex B, permitting a validation for standard systems without additional measurement;

— reference models are extended to different types of contact lines (Clause 11 and Annex A) for easy check of simulations before validation.

This document has been prepared under a mandate given to CENELEC by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For the relationship with EU Directive 2008/57/EC see informative Annex ZZ, which is an integral part of this document.

Annexes designated “normative” are part of the body of the standard. In this standard, Annex A and Annex B are normative.

1 Scope

Simulation techniques are used to assess the dynamic interaction between overhead contact lines and pantographs, as part of the prediction of current collection quality. This document specifies functional requirements for the validation of such simulation methods to ensure confidence in, and mutual acceptance of the results of the simulations.

This document deals with:

– input and output parameters of the simulation;

– comparison with line test measurements, and the characteristics of those line tests;

– validation of pantograph models;

– comparison between different simulation methods;

– limits of application of validated methods to assessments of pantographs and overhead contact lines.

This document applies to the current collection from an overhead contact line by pantographs mounted on railway vehicles. It does not apply to trolley bus systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 50119:2009, *Railway applications — Fixed installations — Electric traction overhead contact lines*

EN 50206-1:2010, *Railway applications — Rolling stock — Pantographs: Characteristics and tests — Part 1: Pantographs for main line vehicles*

EN 50317:2012, *Railway applications — Current collection systems — Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line*

EN 50367:2012, *Railway applications — Current collection systems — Technical criteria for the interaction between pantograph and overhead line (to achieve free access)*

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/

- ISO Online browsing platform: available at http://www.iso.org/obp

NOTE Further definitions from the Normative References can be used.

3.1
contact point
<for a pantograph> location of mechanical contact between a pantograph contact strip and a contact wire

3.2
contact force
<for a pantograph> vertical force applied by a pantograph to the contact wire(s)

Note 1 to entry: The contact force is the sum of the forces of all contact points of a pantograph.

3.3
static contact force
vertical force exerted upward by the collector head on the overhead contact line system at standstill

[SOURCE: EN 50206-1:2010, 3.3.5]

3.4
aerodynamic force
vertical force applied to the pantograph as a result of air flow around the pantograph components

3.5
mean contact force
statistical mean value of the contact force

[SOURCE: EN 50317:2012, 3.5]

3.6
standard deviation
square root of the sum of the squared sample variance divided by the number of output values minus 1

3.7
skewness
parameter that quantifies the symmetry of the shape of a data distribution

$$sk = \frac{\sum \frac{\left(F - F_m\right)^3}{n}}{\left(\sum \frac{\left(F - F_m\right)^2}{n}\right)^{\frac{3}{2}}} \qquad (1)$$

3.8
excess of kurtosis
parameter that quantifies whether the shape of the data distribution matches the Gaussian distribution

$$ek = \frac{\sum \frac{\left(F - F_m\right)^4}{n}}{\left(\sum \frac{\left(F - F_m\right)^2}{n}\right)^{2}} - 3 \qquad (2)$$

3.9
minimum of contact force
minimum value of the contact force while the pantograph passes over the analysis section

3.10
maximum of contact force
maximum value of the contact force while the pantograph passes over the analysis section

3.11
loss of contact
physical separation of the collector head from the contact wire

Note 1 to entry: In simulation this condition occurs when the contact force is zero or less.

3.12
simulation method
numerical method that uses a fixed set of input parameters describing a system (e.g. pantograph/overhead contact line system) to calculate a set of output values representative of the dynamic behaviour of this system

3.13
pantograph model
mathematical model in a one- or more-dimensional geometry describing the dynamic characteristics of the pantograph

3.14
mass – spring – damper – model
lumped parameter model
method representing a dynamic mechanical system (e.g. pantograph) as a series of discrete concentrated masses connected together by spring and damper elements

3.15
transfer function <of a pantograph>
ratio of an applied input to the response of the pantograph, depending on frequency

3.16
apparent mass <of a pantograph>
transfer function describing the relation between applied contact force and resulting acceleration at the contact point for the frequency range of interest

3.17
hardware in the loop
hybrid simulation/test rig measuring method, where a real pantograph responds interacting with a simulation model of the overhead contact line

3.18
multi-body model
method representing a dynamic mechanical system (e.g. pantograph) based on interconnected rigid or flexible bodies

3.19
collector head
part of the pantograph supported by the frame, which includes contact strips, horns and can include a suspension

3.20
overhead contact line model
mathematical model in a two- or three-dimensional geometry describing the characteristics of an overhead contact line for interaction with pantographs

3.21
wave propagation speed of the contact wire
speed of a transversal wave, which runs along the contact wire

3.22
maximum uplift at the support
maximum value of the vertical uplift of the contact wire at a support

3.23
analysis section
subset of the total overhead contact line model length over which the simulation will be evaluated

3.24
frequency range of interest
frequency range within which the dynamic performance of the overhead contact line – pantograph system is considered

Note 1 to entry: For validation with measurements this range correlates with the frequency range defined in EN 50317.

3.25
dynamic interaction
behaviour between pantograph(s) and overhead contact line in contact, described by contact forces and vertical displacements of contact point(s)

3.26
frequency band analysis
analysis inside a frequency range of interest using subranges of frequencies to study special topics

3.27
elasticity of overhead contact line
uplift divided by the force applied to the contact wire in a static state

3.28
range of vertical position of the point of contact
difference between maximum and minimum dynamic height of the contact point, relative to the track, during dynamic interaction between the pantograph and the contact wire

4 Symbols and abbreviations

For the purpose of this document, the following symbols and abbreviations apply.

Abbreviations:

AW	auxiliary wire
CT	centre of the track
CW	contact wire
CWH	contact wire height
HIL	hardware in the loop
MT	type of support
MW	messenger wire
Mxx	support or mast number
OCL	overhead contact line
SDx	number of dropper to stitch wire
STx	span type number as reference to Figure Span number
SW	stitch wire

Symbols:

$a_{cp,meas}$	measured vertical acceleration at the contact point
$a_{cp,model}$	simulated vertical acceleration at the contact point
C_s	structural damping matrix
c_n	damping of element n
Dx	dropper number
E	modulus of elasticity
e	elasticity of contact line
ek	excess of kurtosis of contact force
F	contact force
$F_{applied,meas}$	measured vertical force applied at the contact point
$F_{applied,model}$	simulated vertical force applied at the contact point
f_i	actual frequency
F_m	mean contact force
f_n	maximum frequency
F_{sa}	lateral force at steady arm
f_1	minimum frequency
K	stiffness matrix
k_n	stiffness of element n
L_{dr}	dropper length
Lx_{dr}	dropperlength (for CW no. x)
L_{sa}	length of steady arm
M	mass matrix
$m_{app,meas}$	measured apparent mass
$m_{app,model}$	apparent mass of the model
m_n	mass of element n
Q	accuracy of the pantograph simulation model
sk	skewness of contact force
X	distance between left mast and dropper no. x
α, β	proportional damping coefficients
σ	standard deviation of contact force

5 General

5.1 Typical application

One of the purposes of the application of this standard is to inform the process for seeking authorization for an OCL or pantograph design. In Annex C, Figure C.1 shows the route through to assessment of an OCL system in accordance with the ENE TSI [1], and Figure C.2 the assessment of a pantograph in accordance with the LOC & PAS TSI [2], for European Interoperability.

NOTE Other applications, not related to TSI authorizations (e.g. research, technical development, etc), may require a different process.

5.2 Overview of the validation process

The theoretical study of the dynamic interaction between pantograph and overhead contact line by computer simulation makes it possible to obtain much information about the system and to minimize the costs of line tests.

In order to be used with confidence the simulation method shall be validated. The validation for a simulation method shall be done in a process described in Figure 1.

A simulation method validated according to this standard, shall be considered for application to overhead contact line/pantograph combinations and conditions only within the limits of validity defined in 10.3.

A new validation shall be made when the conditions to apply simulation are outside the limitations defined in 10.3 for existing validations.

The validation for a simulation method shall be done with the steps which are shown in Figure 1. The steps are:

1) A first validation step shall be done by a “desktop assessment” in accordance to Clause 11. The most relevant reference model data shall be chosen from the reference models in Annex A for the conditions for which validation is required.

   NOTE This desktop assessment will improve the confidence in the simulation method. As Annex A cannot cover all possible solutions and combinations a choice from this subset is necessary.

   For validation of simulation methods implemented for new technologies in ways that are totally different from the current state of the art, and which are not able to use models with the data according to Annex A, the “desktop assessment” may be omitted.

2) The final assessment shall be done by a “Line Test Data Validation” based on test results according to 10.1 to demonstrate the accuracy of simulation according to 10.2.

   Annex B provides data sets from line test measurements in accordance with EN 50317 to allow for a validation for a given model within the limitations according to 10.3.

If the accuracy according to either 10.2 or to 11.4 cannot be achieved then the simulation method shall be improved according to 6.3 for pantograph model adjustments and according to 7.3 for contact line model before revalidation.

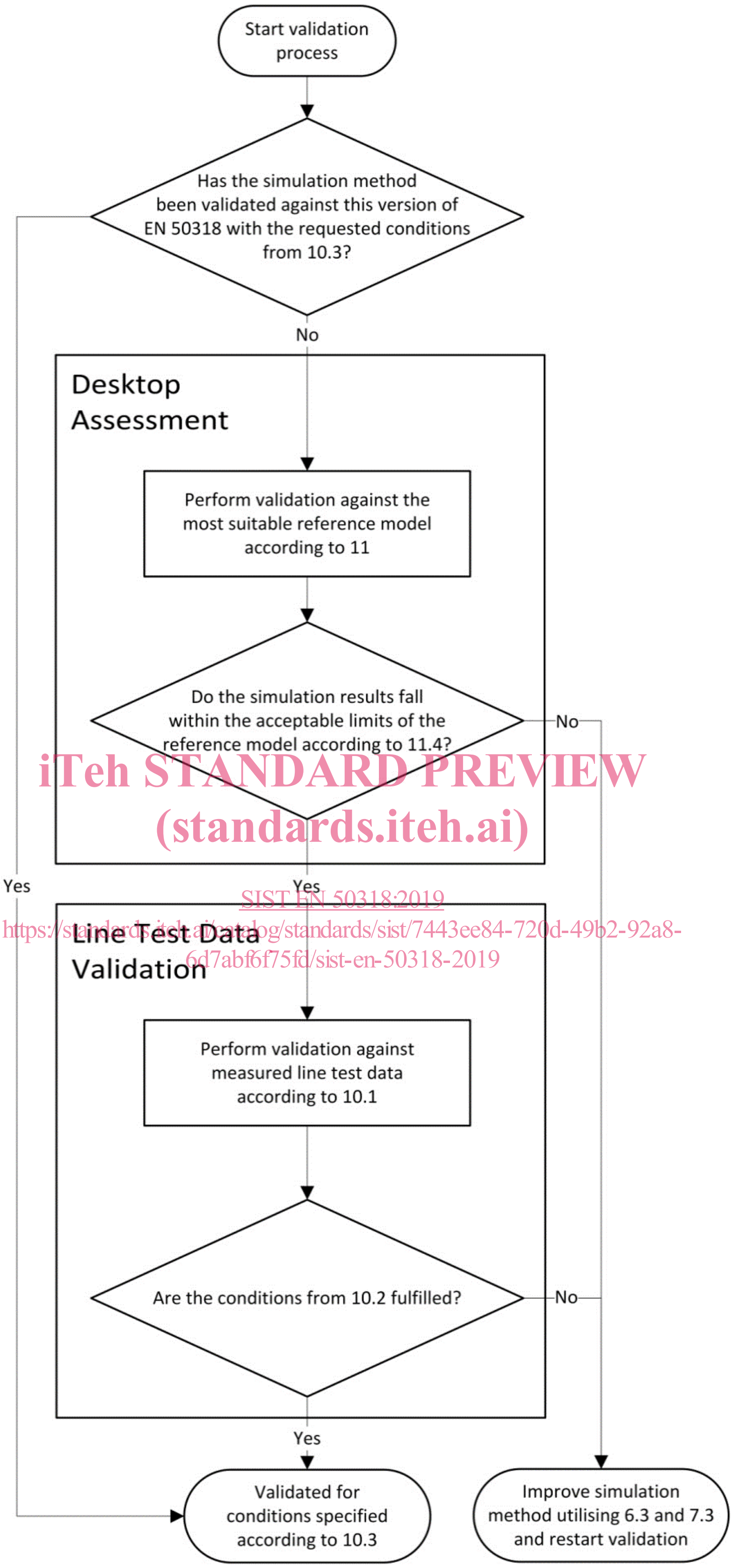

Figure 1 — Evaluation process

6 Modelling of the pantograph

6.1 General requirements

A pantograph model shall describe the dynamic characteristics of a pantograph, regarding interaction with overhead contact lines, in the frequency range of interest.

Commonly used pantograph models are:

– mass – spring – damper – models (lumped parameter models);

– transfer function models;

– multi-body models;

– physical pantographs, when hardware in the loop (HIL) is adopted.

The pantograph may be modelled with one or more dimensional geometry, depending on the phenomena to be investigated.

For the modelling of active pantographs the characteristics of control and the dynamic characteristics shall be available.

Aerodynamic effects on the pantograph shall as a minimum be considered by enhancing the mean contact force as a function of speed.

6.2 Input data requirements

6.2.1 General

Depending on the modelling method and the individual pantograph characteristics, the relevant parameters appropriate to fully describe the pantograph shall be available for simulation.

These parameters shall take into account other dependencies (operation height, stagger, nonlinearities, frequency), as required.

Common parameters of pantographs are:

– kinematics;

– transfer function;

– natural frequencies;

– mass distribution;

– degree of freedom of joints;

– damping characteristics;

– spring characteristics;

– friction values;

– stiffness;

– bump stops;

– location of application of the static contact force;

– location of application of the aerodynamic forces.

NOTE Aerodynamic forces usually depend on the orientation, operation height and position of the pantograph and the type of train.

6.2.2 Mass – spring – damper – models (lumped parameter models)

For mass – spring – damper – models (lumped parameter models), the following input is required:

– mass values of a minimum of two discrete mass elements;

– stiffness characteristics connecting the discrete masses, including any nonlinearity (if applicable);

– damping characteristics connecting the discrete masses, including any nonlinearity (if applicable);

– friction values (if applicable);

– bump stops (if applicable);

– application points of static and aerodynamic forces.

6.2.3 Multi-body models

For multi-body models, the following additional input is required:

– definition of all parts of the model including mass distributions, inertia characteristics, flexibility (if applicable);

– kinematics, describing transmission of movements, kinds of joints and their position and limitations (if applicable);

– internal forces applied to the system and their application points for springs, dampers and friction elements;

– application points of static and aerodynamic forces.

6.2.4 Transfer function models

For transfer function models the following input is required:

– an analytical definition of the Laplace transform function, e.g. zeros and poles inside the frequency range of interest, between the vertical displacement of the contact point and the contact force.

6.2.5 Hardware in the loop

Hardware in the loop uses the pantograph in its final configuration on the test rig. Aerodynamic effects shall be implemented as an adjusted static contact force.

6.3 Validation of pantograph models

The validation of the pantograph models shall be carried out by comparison of the dynamic properties of the pantograph model with those of the real pantograph as measured with a pantograph test rig. The comparison shall be carried out using the same principle as used in the procedure “Calibration of the measurement system” defined in EN 50317:2012, 7.5.

The test shall be carried out with the pantograph of interest and with its extension at a typical height inside 20 % to 80 % of the working range, as defined in EN 50206-1. The force shall be applied centrally to the pantograph head.

The results are usable for 20 % to 80 % of the pantograph working range. Values outside this range require additional investigations.

This test shall be carried out at the predicted mean contact force appropriate to the maximum design speed for the pantograph. The mean contact force shall fulfil the requirements of EN 50367:2012, 7.3, Table 6 for the designated speed.