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

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



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RAILWAY APPLICATIONS – CURRENT COLLECTION SYSTEMS –
VALIDATION OF SIMULATION OF THE DYNAMIC INTERACTION
BETWEEN PANTOGRAPH AND OVERHEAD CONTACT LINE**

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Draft	Report on voting
9/3145/FDIS	9/3163/RVD

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RAILWAY APPLICATIONS – CURRENT COLLECTION SYSTEMS – VALIDATION OF SIMULATION OF THE DYNAMIC INTERACTION BETWEEN PANTOGRAPH AND OVERHEAD CONTACT LINE

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 tools 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 tools;
- 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.

IEC 60494-1:2013, *Railway applications – Rolling stock – Pantographs – Characteristics and tests – Part 1: Pantographs for main line vehicles*

IEC 60913:2024, *Railway applications – Fixed installations – Electric traction overhead contact line systems*

IEC 62846:2016, *Railway applications – Current collection systems – Requirements for and validation of measurements of the dynamic interaction between pantograph and overhead contact line*

IEC 62486:2017, *Railway applications – Current collection systems – Technical criteria for the interaction between pantograph and overhead contactline (to achieve free access)*

3 Terms and definitions

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

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

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

contact point

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

3.2

contact force

F

<for a pantograph> vertical force applied by a pantograph to the overhead contact line

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

3.3

static contact force

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

[SOURCE: IEC 60494-1:2013, 3.3.5]

3.4

aerodynamic force

additional vertical force applied by the pantograph as a result of air flow around the pantograph assembly

3.5

mean contact force

F_m

statistical mean value of the contact force

Note 1 to entry: F_m is formed by the static and aerodynamic components of the pantograph contact force.

[SOURCE: IEC 62486:2017, 3.11]

3.6

standard deviation

<of contact force> square root of the sum of the squared sample variance divided by the number of output values minus 1

3.7

skewness

sk

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

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

3.8
excess of kurtosis
ek

parameter that quantifies whether the shape of the data distribution matches the Gaussian distribution

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

3.9
minimum contact force

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

3.10
maximum contact force

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

3.11
contact loss

condition where the contact force is zero

Note 1 to entry: Contact loss surely induces arcing except in the case of coasting. However, if two or more pantographs are connected electrically each other, arc will immediately disappear and then the condition will shift to "current loss".

[SOURCE: IEC 62486:2017, 3.22]

3.12
simulation method

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

3.13
simulation tool

software implementing one or more simulation methods

3.14
pantograph model

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

3.15**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

3.16**transfer function**

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

3.17**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

3.18**hardware in the loop**

hybrid method (simulation and dynamic laboratory test), where a real pantograph responds interacting with a simulation model of the overhead contact line

3.19**multi-body model**

method representing a dynamic mechanical system (e.g. pantograph) based on interconnected rigid or flexible bodies

3.20**pantograph head
pantograph pan**

part of the pantograph comprising the contact strips and their mountings, horns and possibly a suspension

[SOURCE: IEC 60050-811:2017, 811-32-05]

3.21**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

3.22**compound catenary**

overhead contact line with one or two contact wires suspended from an auxiliary messenger wire which is suspended from the main messenger wire

[SOURCE: IEC 60050-811:2017, 811-33-12 modified: catenary wire to messenger wire, deleted: equipment]

3.23**messenger wire**

longitudinal cable supporting the contact wire or wires either directly or indirectly

[SOURCE: IEC 60050-811:2017, 811-33-06, deleted: catenary wire]

3.24**wave propagation velocity**

<of the contact wire> speed of a transversal wave, which runs along the contact wire

3.25**contact wire height**

distance from the top of the rail to the lower face of the contact wire at rest position without pantograph contacted

Note 1 to entry: The contact wire height is measured perpendicular to the track.

[SOURCE: IEC 60050-811:2017, 811-33-62 modified; added: at rest position; deleted: (or road surface for overhead contact line system for trolleybus applications)]

3.26**maximum uplift at the support**

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

3.27**analysis section**

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

3.28**frequency range of interest**

frequency range within which the dynamic performance of the overhead contact line and pantograph system is considered

Note 1 to entry: For validation with measurements this range correlates with the frequency range defined in IEC 62846.

3.29**dynamic interaction**

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

3.30**frequency band analysis**

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

3.31**elasticity of overhead contact line**

uplift divided by the force applied to the contact wire in a static state

3.32**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

3.33**operation height**

vertical distance between actual operating position of the pantograph and pantograph's housed height

3.34**active pantograph**

pantograph fitted with any type of active control system which enhances or alters its dynamic response

4 Symbols and abbreviated terms

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

Abbreviated terms:

AC	Pertaining to alternating electric quantities such as voltage or current, to devices operated with these, or to quantities associated with these devices
CT	Centre of the track
CW	Contact wire
CWH	Contact wire height
CW1H	Height of contact wire 1
CW2H	Height of contact wire 2
DC	Pertaining to time-independent electric quantities such as voltage or current, to devices operated with direct voltage and current, or to quantities associated with these devices
FFT	Fast Fourier transformation
HIL	Hardware in the loop
MT	Mast type
MW	Messenger wire
Mxx	Support or mast number
OCL	Overhead contact line
ROCL	Rigid 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 overhead 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_m	Mean contact force
F_{sa}	Lateral force at steady arm
f_i	Actual frequency
f_n	Maximum frequency

Symbols:

f_1	Minimum frequency
K	Stiffness matrix
k_n	Stiffness of element n
L_{dr}	Dropper length
Lx_{dr}	Dropper length (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
n	Number of contact force values
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 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.

To be used with confidence the simulation tool shall be validated. The validation for a simulation tool shall be done in a process described in Figure 1.

A simulation tool validated according to this document, 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.