SLOVENSKI STANDARD
SIST EN 50641:2020

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Železniške naprave - Stabilne naprave električne vleke - Zahteve za ocenjevanje simulacijskih orodij za snovanje elektroenergetskih napajalnih sistemov električne vleke

Railway applications - Fixed installations - Requirements for the validation of simulation tools used for the design of traction power supply systems

Bahnanwendungen - Ortsfeste Anlagen - Anforderungen für die Validierung von Simulationsprogrammen für die Auslegung von Bahnenergieversorgungssystemen

Applications ferroviaires - Installations fixes - Exigences relatives à la validation des outils de simulation utilisés pour la conception des systèmes d'alimentation de la traction

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Railway applications - Fixed installations - Requirements for the validation of simulation tools used for the design of electric traction power supply systems

Applications ferroviaires - Installations fixes - Exigences relatives à la validation des outils de simulation utilisés pour la conception des réseaux d'alimentation de traction

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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European foreword

This document (EN 50641:2020) has been prepared by CLC/SC 9XC "Electric supply and earthing systems for public transport equipment and ancillary apparatus (Fixed installations)", of Technical Committee 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)	2020-11-04
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2022-11-04

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(s) see informative Annex ZZ, which is an integral part of this document.

Experts representing approximately ten member states worked to draft a complete new document. The results and data are taken from the most well-known representative simulation softwares in Europe and related experts. This document provides a means of assessing simulation tools and provides assurance to anyone who depends upon their output. Future versions will include other cases such as urban traffic.

1 Scope

This document specifies requirements for the acceptance of simulation tools used for the assessment of design of electric traction power supply systems with respect to TSI Energy.

This document is applicable to the simulation of AC and DC electric traction power supply systems, in the frame of assessment required by Directive (EU) 2016/797. The methods and parameters defined in this document are only intended for use in the design of the electric traction power supply system, and hence this document solely considers validation of tools within the TSI energy subsystem for all envisaged railway networks.

This document does not deal with validation of simulation tools by measurement.

This document focuses on the core simulation functions comprising the equations and functions which calculate the mechanical movement of trains and also which calculate the load flow of the electrical traction power supply system. In doing so this document provides all requirements necessary to demonstrate that a simulation tool may be used for the purposes of TSI approval of electric traction power supply systems. Any simulation tool which meets the acceptance requirements of the test cases in this document can be used to determine TSI compatibility for all systems of the same voltage and frequency without any requirement for further validation as part of the TSI assessment process.

This document includes controls for the modification of simulation tools, in particular the limits of applicability of certification when tools are modified. These controls focus on determining whether the core functions of the simulation model are modified.

This document provides only the requirements for demonstration of the algorithms and calculations of core functions. The use of a certified simulation tool in accordance with this document does not, in itself, demonstrate good practice in electric traction power supply system design, neither does it guarantee that the simulation models and data for infrastructure or trains used in the tool are correct for a given application. The choice and application of any models and data, of individual system components, in a design is therefore subject to additional verification processes and not in the Scope of this document. Competent development of design models and full understanding of the limits of design tools remain requirements in any system design. This document does not reduce any element of the need for competent designers to lead the design process.

The test cases and data shown in Clause 6 in this document do not represent an existing network, but these data are used as theoretical/virtual network only for the purpose of verification of the core functionality.

NOTE A new test case will be drafted considering metro, tramways and trolleybuses using DC 600 V or DC 750 V. Until this test case is available, this document can also be applied to subway, tram and trolley bus systems. This test case will also integrate rail systems using DC 750 V.

Additionally, the application of this document ensures that the output data of different simulation tools are consistent when they are using the same set of input data listed in Clause 6.

This document only applies to the simulation of electric traction power supply systems characteristics at their nominal frequency for AC or DC systems. It does not consider harmonic studies, electrical safety studies (e.g. rail potential), short circuit or electromagnetic compatibility studies over a wide frequency spectrum. This document does not mandate the use of a particular simulation tool in order to validate the design of an electric traction power supply system.

This document does not consider complex models with active components such as static frequency convertors.

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 50163:2004, *Railway applications - Supply voltages of traction systems*

EN 50388:2012, *Railway Applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 50163:2004, EN 50388:2012 and the following 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

3.1
assessor
entity that carries out an assessment

[SOURCE IEC 60050-821:2017, 821-12-05]

3.2
electric traction system
electric traction power supply system
railway electric distribution network used to provide energy for rolling stock

[SOURCE: IEC 60050-811:2017, 811-36-21, modified – “electric traction power supply system” has been added as synonym and the Note 1 to entry has been removed.]

3.3
proposer
organization which proposes the simulation and validation

Note 1 to entry: This will normally be the software owner and or developer.

3.4
simulation accuracy
indicator dedicated to the characterization of the accuracy of the simulation output regarding a reference (measure or theoretical model) for a given case

3.5
simulation method
construction and solution of a numerical time-step or space-step model of train movement and electric traction power supply performance

3.6
simulation tool
software implementing a simulation method(s)

3.7
software quality management
management system for software to be updated

Note 1 to entry: The processes are the following:

— software development process comprising the steps of development request, software test, release;

— life cycle process with the steps release plan, versioning with code protection and changelog, bug tracking, documentation (user manual, help system, developer's guide if any).

3.8
track layout model
model describing the physical characteristics of the track such as curves, tunnels and gradient description

3.9
train set
combination of vehicles coupled together

Note 1 to entry: Vehicle includes banking locomotives.

3.10
train set model
model describing the electrical and mechanical characteristics of the train set

3.11
train traffic model
model of the train service and the timetable over a given time period

3.12
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: Verification is a prerequisite for validation.

[SOURCE: IEC 60050-192:2015, 192-01-18, modified – Notes 1 to 5 to entry have been removed and a new Note 1 to entry has been added.]

3.13
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: Whilst the general term in this document is assessment, verification is commonly understood in the assessment of models and data analysis and its use is more specific than the general term conformity.

[SOURCE: IEC 60050-192:2015, 192-01-17, modified – Notes 1 to 3 to entry have been removed and a new Note 1 to entry has been added.]

4 Symbols and abbreviated terms

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

A	coefficient of running resistance independent of speed
a	knee point factor (see EN 50388:2012, 7.2)
AT	autotransformer
ATPP	autotransformer paralleling post including paralleling of CLS
B	coefficient of running resistance for linear dependence of speed
C	coefficient of running resistance for quadratic dependence of speed
CLS	contact line system (overhead contact line or third rail)
$\cos \varphi$	power factor for the traction and auxiliary power
EMU	electrical multiple unit
F	tractive effort
F_m	maximum tractive effort
FR	freight train set
F_{res}	running resistance
HS	high speed train set NOTE This name is used as a general term and does not relate to similar definitions given in Directive (EU) 2016/797.
I	current
I_{aux}	current for train set auxiliaries (e.g. air conditioning)
$I_{braking}$	braking current of the train set
I_{max}	maximum current consumed by the train set at U_n
Ind	inductive behaviour
N/A	not applicable
P_{aux}	auxiliary active power
P_{max}	maximum mechanical power
PP	paralleling post where CLS of both tracks are electrically connected
R_{eq}	equivalent internal resistance of a substation
SP	sectioning point of the CLS for each track.
SS	substation including paralleling of CLS
SUB	suburban train set
TSI	technical specification of interoperability
U_{di0}	no load voltage at a substation for DC traction system
U_0	no load voltage at a substation for AC traction system
U_{cc}	short circuit voltage of a transformer
UIC60	rail profile with a mass of 60 kg/m
U_{max1}	highest permanent voltage (see EN 50163:2004)
U_{max2}	highest non-permanent voltage (see EN 50163:2004)
$U_{mean\ useful}$	mean useful voltage (see EN 50388:2012, 8.2)
U_{min2}	lowest non-permanent voltage (see EN 50163:2004)

U_n	nominal voltage for a given electrical supply system
U_p	current collector voltage
V	speed in km/h
v_1	transfer speed 1 (transfer from adhesion characteristic to maximum voltage characteristic of drive)
v_2	transfer speed 2 (transfer from maximum voltage characteristic to torque limitation characteristic of drive)
v_3	maximum speed
v_{max}	maximum allowed speed (track, train set)
Z_{TR}	transformer impedance
η	traction/braking efficiency
μ_r	relative permeability

5 General

This document considers the acceptance of typical impedance based models of electric traction power supply systems at fundamental frequency or DC. Both lumped and multiconductor impedance models are covered, but this document does not consider complex models of active components such as a static frequency converter.

The theoretical study of the interactions between the operation of rolling stock and the power supply system by means of computer simulation is generally used to obtain detailed information about a traction power system. This minimizes the costs of live tests, and as a consequence optimizes the investment to be made for a given performance of the electrical railway system.

Depending on the type of the supply system (for example: AC or DC system), the simulation tools require different data and different system descriptions. Therefore the scope of the simulation should be defined in advance, taking account of possible supply systems (see Figure 1). The assessment process of the simulation is in two parts. Firstly, a validation process is undertaken which compares in a qualitative way specific characteristics of the key simulation output graphs, in order to validate the performance of the simulation at critical events. Secondly, the quantitative verification of the simulation is assessed by comparing key calculated values with those given in this document. The verification process laid out in this document is based on a verification using a defined benchmark example of an electric traction power supply system, and employing a common set of input data incorporating the infrastructure (including station locations, gradient, speed limit), types of train sets and timetable.

NOTE The output data sets have been developed through assessment with several existing simulation tools, currently used in electric traction power supply system design, and which therefore represent a range of differences within core algorithms. The simulation accuracy of the outputs from these tools were compared, and tolerances applied to cover the range of variation considered reasonable across all tools. The observed variation in these tools has no effect on their applicability for use in TSI assessments, and hence this range of tolerance can be applied to the acceptance of new tools. Annex C gives information on the calculation methodology of tolerances for determination of applied boundary values.

The following cases are provided in the standard:

— DC 1,5 kV,

— DC 3 kV,

— AC 15 kV, lumped element,

— AC 25 kV, lumped element,

— AC 25 kV, multi-conductor model,

— AC 2x25 kV, multi-conductor model.

In order to obtain an acceptable verification of a simulation tool, the results of the simulation tool shall be compared with the output results presented in this document according to the criteria described in Annexes A and B.

In order to use a simulation tool with confidence, it shall be validated initially and after each revision of the core functions of the software that have an impact on the simulation results. If the modification affects a core function then a new validation is necessary. The validation shall be done by following the steps shown in Figure 1.

Core functions of the simulation tools are the algorithms to:

— solve the differential equations of train sets movement resulting in power demand at current collector(s);

— calculate the load flow (current-voltage) of the electrical network with changing configurations caused by moving loads.

Interaction between mechanical and electrical core functions are required to provide an integrated solution, where lack of electrical power will feedback to influence the train set movement including iterations as necessary.

The core functionality comprises the algorithms of mechanical train movement, the electrical network load flow, and the interaction between mechanical and electrical core functions required to provide an integrated solution.

Changes to these core functions, and also functions outside the core such as interaction with the user, presentation and pre-processing of data and models before passing to the core, and all post-processing of data from the core, do not require full validation by an assessor. If a validated simulation tool has been certified, the organization holding the certificate may asses such changes, subject to the requirements for internal software quality management to provide a traceable audit process to these changes.

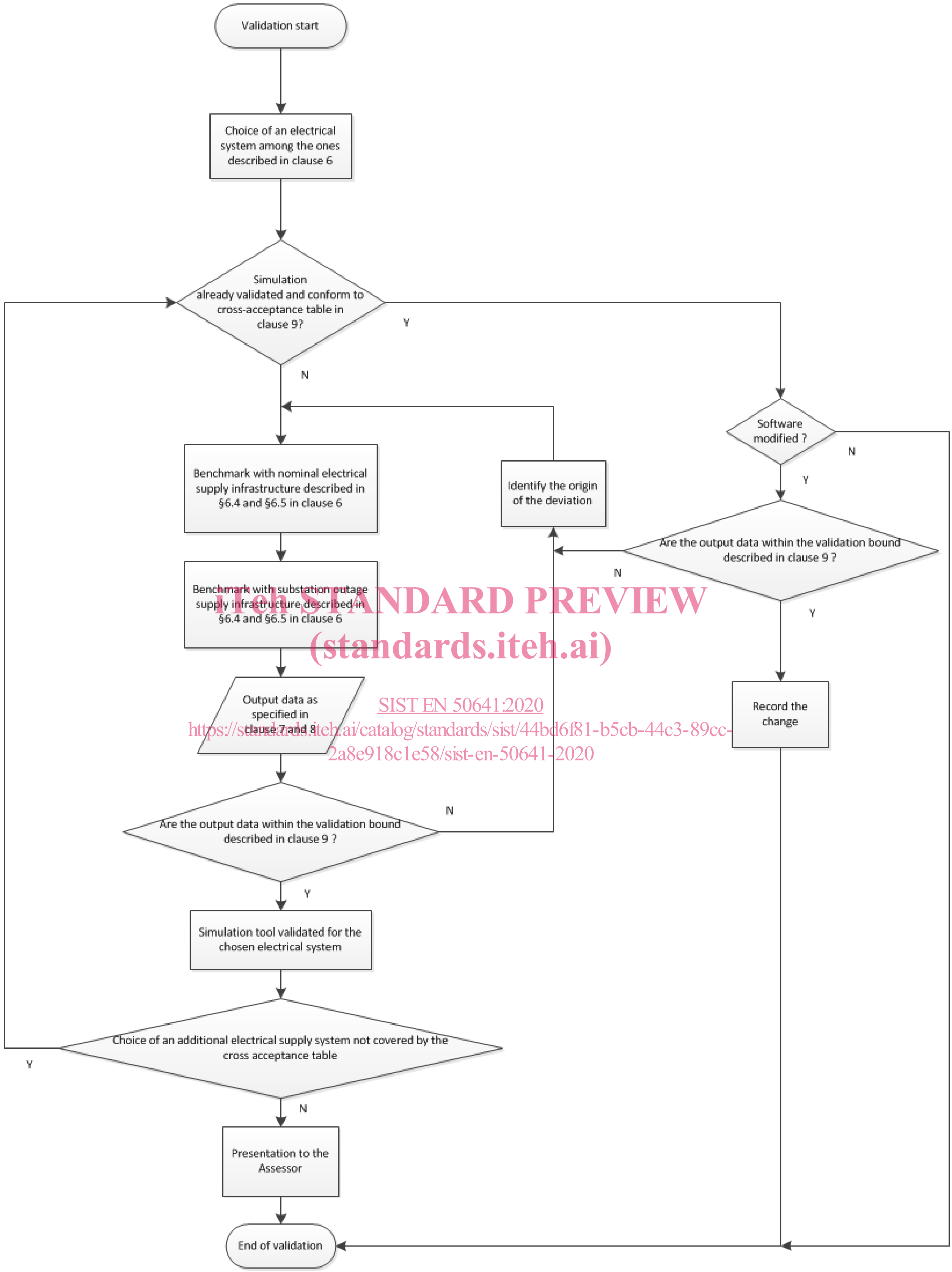

Figure 1 — Steps of validation

6 Test and models description

6.1 General

Common parameters for both AC and DC systems are given in 6.2 and 6.3. Parameters specific to DC and AC systems are given respectively in 6.4 and 6.5.

The test case configurations and data are used for the purpose of the standard only. They do not represent typical applications for system design.

6.2 Common parameters

The test case describes simple traffic along a given open air double track straight line. Although there are some differences due to the different supply systems, some parameters remain identical among the test cases, in particular:

— traffic timetable;

— train set.

The maximum track operational speed is 200 km/h for all train types.

The general description of the case is described in Figure 2. Distances are indicated in Tables 2 and 3 for DC cases and Tables 6 and 7 for AC cases.

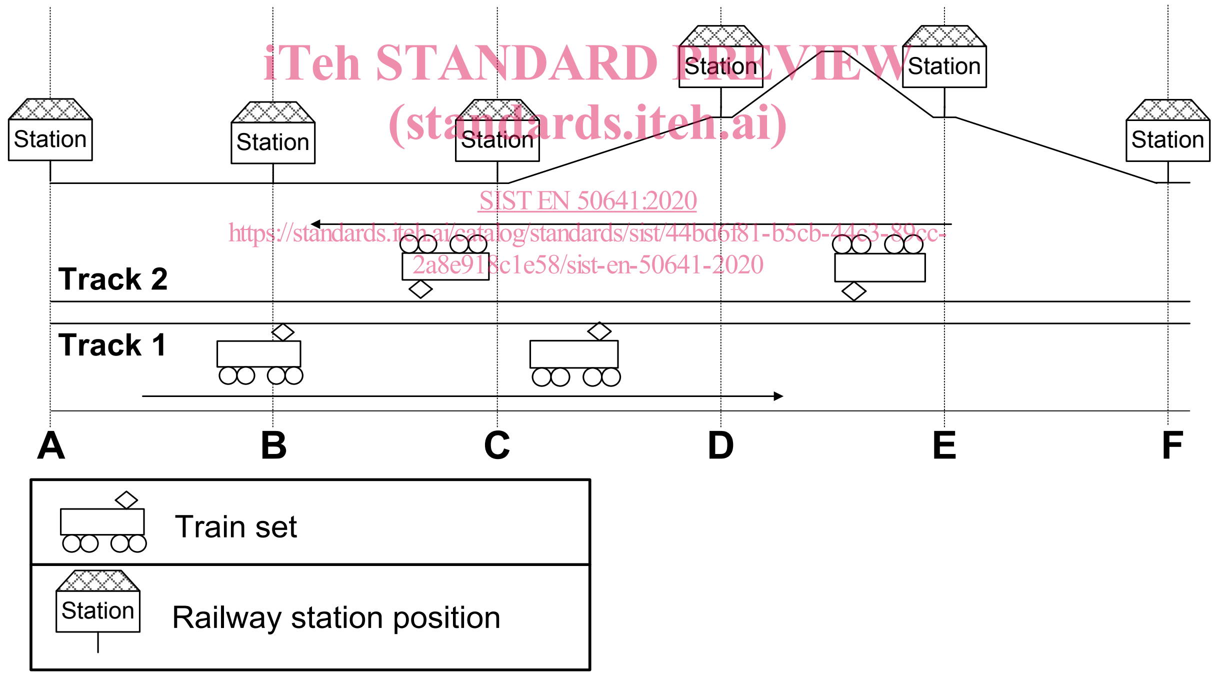

Figure 2 — Test case general description

Three different kinds of train set are defined throughout the test case:

a) high speed train set;

b) suburban train set;

c) freight train set.

6.3 Train set descriptions

6.3.1 Type of train set and mechanical characteristics

The mechanical characteristics for the three different kinds of train set of this test case are provided as follows:

a) high speed train set (HS): locomotive and coaches;

b) suburban train set (SUB): EMU;

c) freight train set (FR): locomotive and wagons.

The parameters shall be as specified in Table 1.

Table 1 — Train set mechanical and traction characteristics

Type	Unit	HS	SUB (2 units)	FR
Speed v_1	km/h	110	50	80
Speed v_2	km/h	180	140	140
Speed v_3	km/h	220	160	160
Maximum allowed train set speed	km/h	220	160	100
Maximum Tractive effort F_m	kN	250	320	250
Tractive effort at v_2	kN	152,8	114,3	143
Tractive effort at v_3	kN	102	87,5	109,4
Total mass	t	580	400	1 580
Rotating mass	t	58	40	158
Efficiency (η)	-	85 %	85 %	85 %
Power factor at the pantograph (traction / braking and auxiliaries)[a]	-	0,96 ind.	0,96 ind.	0,96 ind.
Auxiliary active power P_{aux}	MW	0,5	0,4	0
A	kN	9,23	3,351 6	24,3
B	kN/(km/h)	0,015 8	0,008 208	0,084 7
C	kN/(km/h)^2	0,001 23	0,000 66	0,004 03
Locomotive(s)	-	1	2 (EMU)	1
Coaches/wagon	-	10	-	25
Max permissible deceleration	m/s^2	0,8	1	0,5

[a] Applicable only to the AC cases; for DC cases the power factor is 1.

For the locomotives for the HS and FR train sets, the individual parameters shall be:

— mass : 80 t;

The running resistance shall be defined using a formula: $F_{res} = A + B \times v + C \times v^2$ with v the speed in km/h. The A, B and C coefficients apply to the whole train set.

Additionally, it shall be understood that: