SPECIFICHE TECNICHE D’INTEROPERABILITÀ - ENERGIA

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ERA

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About a TSI

- A TSI is not a manual how to build an ENE subsystem
- It is not possible to build ENE subsystem based only on, and put in service on, TSIs
- A TSI contains only selected requirements which are necessary for interoperability – mainly interfaces with RST

**BUT**

TSI is a legal document - though containing technical requirements - which must be fully obeyed
The energy subsystem consists of:

- **substations**: connected, on the primary side, to a high-voltage grid which can transform the high voltage into a voltage and/or convert it into a power supply system suitable for the trains. On the secondary side, substations are connected to the railway contact line system;

- **sectioning points**: electrical equipment located in intermediate locations between substations to supply and parallel contact lines and to provide protection, isolation and auxiliary supplies;

- **separation sections**: equipment required to make the transition between electrically different systems or between different phases of the same electric system;
The energy subsystem consists of:

- **overhead contact line system**: system that distributes the electricity to the trains running on the line and transmits it to the trains by means of current collection devices. The overhead contact line system is also equipped with manually or remotely controlled disconnectors used to isolate sections or groups of operational needs base. Feeder lines are also part of the contact line system;

- **return circuit**: all conductors which form the intended path for the traction return current. Therefore, so far as this aspect is concerned, the return circuit is part of the energy subsystem and has an interface with the infrastructure subsystem.

- **on-ground energy data collection system**: trackside of the electricity consumption measuring system.
This TSI covers all fixed installations necessary to achieve interoperability that are required to supply traction energy to a train.

The legal text is the Regulation (EU) No 1301/2014 on the technical specifications for interoperability relating to the ‘energy’ subsystem of the rail system in the Union.

Amended by:
- Regulation (EU) 2018/868 of 13 June 2018
- Regulation (EU) 2019/776 of 16 May 2019

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## ENE TSI chapter 3 – Essential Requirements

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<td>1.5</td>
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ENE subsystem

Power supply requirements:
- Voltage and frequency
- Supply system performance
- Current capacity, DC systems, trains at standstill
- Regenerative braking
- Electrical protection coordination arrangements
- Harmonics and dynamic effects for AC systems

Geometry of the OCL and quality of current collection:
- Geometry of OCL
- Pantograph gauge
- Mean contact force
- Dynamic behaviour and quality of current collection
- Pantograph spacing
- Contact wire material
- Phase separation sections
- System separation sections

On-ground energy data collecting system

Protective provisions against electric shock
Power supply
The voltage and frequency of the energy subsystem shall be one of the four systems, specified in accordance with Section 7:

(a) AC 25 kV, 50 Hz;

(b) AC 15 kV, 16,7 Hz;

(c) DC 3 kV;

(d) DC 1,5 kV.
Supply system performance

(a) maximum train current (4.2.4.1);

(b) power factor of trains and the mean useful voltage (4.2.4.2).
Current capacity, DC systems, with trains stationary

The Overhead Contact Line (OCL) of DC systems shall be designed to sustain 300 A (for a 1,5 kV supply system) and 200 A (for a 3 kV supply system), per pantograph when the train is at standstill.

The current capacity at standstill shall be achieved for the test value of static contact force given in table 4 of clause 7.2 of EN 50367:2012.

The OCL shall be designed taking into account the temperature limits in accordance with EN 50119:2009, clause 5.1.2.
• AC power supply systems shall be designed to allow the use of regenerative braking able to exchange power seamlessly either with other trains or by any other means.

• DC power supply systems shall be designed to permit the use of regenerative braking at least by exchanging power with other trains.

• Electrical protection coordination design of the energy subsystem shall comply with the requirements detailed in EN 50388:2012, clause 11.
Harmonised and dynamic effects of AC traction power supply systems

- The power supply system for traction and rolling stock may cause system electrical instability.

- In order to achieve electrical system compatibility, harmonic over voltages shall be limited below critical values according to EN 50388: 2012, clause 10.4.
Overhead Contact Line

Overhead Contact Line
• The overhead contact line shall be designed for pantographs with the head geometry specified in the LOC & PAS TSI, point 4.2.8.2.9.2 taking into account the rules set out in point 7.2.3 of this TSI.

• The contact wire height and the lateral deviation of the contact wire under the action of a cross-wind are factors which govern the interoperability of the rail network.

<table>
<thead>
<tr>
<th>Description</th>
<th>$v \geq 250$ $v &lt; 250$ [km/h]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal contact wire height [mm]</td>
<td>Between 5 080 and 5 750</td>
</tr>
<tr>
<td>Minimum design contact wire height [mm]</td>
<td>5 080</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pantograph length [mm]</th>
<th>Maximum lateral deviation [mm]</th>
</tr>
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<tbody>
<tr>
<td>1 600</td>
<td>400 (1)</td>
</tr>
<tr>
<td>1 950</td>
<td>550 (1)</td>
</tr>
</tbody>
</table>

(1) The values shall be adjusted taking into account the movement of the pantograph and track tolerances according to Appendix D.1.4.
1. No part of the energy sub-system shall enter the mechanical kinematic pantograph gauge (see Appendix D figure D.2) except for the contact wire and steady arm.
1. The mean contact force $F_m$ is the statistical mean value of the contact force. $F_m$ is formed by the static, dynamic and aerodynamic components of the pantograph contact force.

2. The ranges of $F_m$ for each of the power supply systems are defined in EN 50367:2012 Table 6.

3. The overhead contact lines shall be designed to be capable to sustain the upper design limit of $F_m$ given in EN 50367:2012.

4. The curves apply to speed up to 360 km/h. For speeds above 360 km/h procedures set out in point 6.1.3 shall apply.
• Depending on the assessment method, the overhead contact line shall achieve the values of dynamic performance and contact wire uplift (at the design speed) set out in Table 4.2.12.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement</th>
<th>$v \geq 250 &gt; v_v \geq 160 [\text{km/h}]$</th>
<th>$v &gt; 250$ [\text{km/h}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space for steady arm uplift</td>
<td>$S_0$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean contact force $F_m$</td>
<td>See 4.2.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation at maximum line speed $v_{\text{max}} [\text{km/h}]$</td>
<td>$0.3F_m$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of arcing at maximum line speed, NQ [%] (minimum duration of arc 5 ms)</td>
<td>$\leq 0.2$ for AC systems</td>
<td>$\leq 0.1$ for DC systems</td>
<td>$\leq 0.1$</td>
</tr>
</tbody>
</table>
The overhead contact line shall be designed for a minimum of two pantographs operating adjacently. The design spacing of the two adjacent pantograph heads, centre line to centre line, shall be equal or lower than values set out in one column ‘A’, ‘B’, or ‘C’ selected from Table 4.2.13:

<table>
<thead>
<tr>
<th>Design speed [km/h]</th>
<th>AC Minimum distance [m]</th>
<th>DC Minimum distance [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>250 ≤ v &lt; 160</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>160 ≤ v &lt; 120</td>
<td>85</td>
<td>35</td>
</tr>
<tr>
<td>120 ≤ v &lt; 80</td>
<td>85</td>
<td>35</td>
</tr>
<tr>
<td>80 ≤ v ≤ 120</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>v ≤ 80</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>
(1) The combination of contact wire material and contact strip material has a strong impact on the wear of contact strips and contact wire.

(2) Permissible contact strip materials are defined in point 4.2.8.2.9.4.2 of LOC&PAS TSI.

(3) Permissible materials for contact wires are copper and copper-alloy. The contact wire shall comply with the requirements of EN 50149:2012, clauses 4.2, (excluding the reference to annex B of the standard) 4.3 and 4.6 to 4.8.
The design of phase separation sections shall ensure that trains can move from one section to an adjacent one without bridging the two phases.

Power consumption of the train (traction, auxiliaries and no-load current of the transformer) shall be brought to zero before entering the phase separation section.

Adequate means (except for the short separation section) shall be provided to allow a train that is stopped within the phase separation section to be restarted.
The design of system separation sections shall ensure that trains can move from one power supply system to an adjacent different power supply system without bridging the two systems.

There are two methods for traversing system separation sections:

- with pantograph raised and touching the contact wire;
- with pantograph lowered and not touching the contact wire.

The neighboring Infrastructure Managers shall agree either (a) or (b) according to the prevailing circumstances.

- (pantographs lowered)
  - If a system separation section is traversed with pantographs lowered, it shall be designed so as to avoid the electrical connection of the two power supply systems by an unintentionally raised pantograph.
Trackside Energy Data Collection System
On-ground energy data collecting system

- On-ground energy data collecting system

- Point 4.2.8.2.8 of LOC & PAS TSI contains the requirements for on-board Energy Measurement Systems (EMS) intended to produce and transmit the Compiled Energy Billing Data (CEBD) to an on-ground energy data collecting system.

- The on-ground energy data collecting system (DCS) shall receive, store and export CEBD without corrupting it, in accordance with the requirements quoted in clause 4.12 of EN 50463-3:2017.

- The on-ground energy DCS shall support all the data exchange requirements as defined in point 4.2.8.2.8.4 of the LOC&PAS TSI and requirements set out in clauses 4.3.6 and 4.3.7 of EN 50463-4:2017.
Provisions concerning protection against electric shock
Provisions concerning protection against electric shock

- Electrical safety of the overhead contact line system and protection against electric shock shall be achieved by compliance with EN 50122-1:2011+A1:2011, clauses 5.2.1 (only for public areas), 5.3.1, 5.3.2, 6.1, 6.2 (excluding requirements for connections for track circuits) and regarding AC voltage limits for the safety of persons by compliance with 9.2.2.1 and 9.2.2.2 of the standard and regarding DC voltage limits by compliance with 9.3.2.1 and 9.3.2.2 of the standard.
Interoperability constituent
The interoperability constituent overhead contact line consists of the components listed below to be installed within an energy subsystem and the associated design and configuration rules.

The components of an overhead contact line are an arrangement of wire (s) suspended over the railway line for supplying electricity to electric trains, together with associated fittings, in-line insulators and other attachments including feeders and jumpers. It is placed above the upper limit of the vehicle gauge, supplying vehicles with electrical energy through pantographs.

The supporting components such as cantilevers, masts and foundations, return conductors, self-processing power supplies, disconnectors and other insulators are not part of the interoperability constituent overhead contact line. They are covered by subsystem requirements so far as interoperability is concerned.
• The main goal of this test is to identify allocation design and construction errors but not to assess
the basic design in principle.
• Measurements of the interaction parameters shall be carried out in accordance with EN 50317: 2012.
• These measurements shall be carried out with an interoperability constituent pantograph, exhibiting the mean contact force characteristics as required by point 4.2.11 of this TSI for the design speed of the line considering aspects related to minimum speed and siding tracks.
• The installed overhead contact line shall be accepted if the measurement results comply with the requirements in point 4.2.12.
• For operational speeds up to 120 km/h (AC systems) and up to 160 km/h (DC systems), measurement of the dynamic behaviour is not mandatory. In this case alternative methods of identifying construction errors shall be used, such as measurement of OCL geometry according to point 4.2.9.
Implementation of the ENE TSI

ENE TSI chapter 7
Member States’ implementation plan shall consider the following elements:

a) fill the gaps between the different geometries of the OCL;

b) any connection to the existing OCL geometries in neighboring areas;

c) existing certified ICs OCL.

The OCL shall be designed considering the following rules:

a) New lines above 250 km/h shall allow the use of both pantographs as referred to in points 4.2.8.2.9.2.1 (1 600 mm) and 4.2.8.2.9.2.2 (1 950 mm) of the TSI LOC & If this is not possible, the overhead contact line shall be designed for use with at least one pantograph with the head geometry specified in point 4.2.8.2.9.2.1 of the TSI LOC & PAS (1 600 mm).

b) Renewed or upgraded lines with a speed greater than or equal to 250 km/h shall allow the use of at least a pantograph with the head geometry referred to in point 4.2.8.2.9.2.1 of the TSI LOC & PAS (1 600 mm).

c) Other cases: The overhead contact line shall be designed for at least one of the pantographs with the head geometry specified in points 4.2.8.2.9.2.1 (1 600 mm) or 4.2.8.2.9.2.2 (1 950 mm) of the TSI LOC & PAS.
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• Particular features on the Italian rail network — P case
• Phase separation sections — lines with speed $v > 250$ km/h (4.2.15.2)
• In case of upgrading/renewal of high speed line Rome-Naples special design of phase separation sections is allowed.