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**COMMISSION DECISION**

**of 30 May 2002**

**concerning the technical specification for interoperability relating to the energy subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC**

*(notified under document number C(2002) 1949)*

**(Text with EEA relevance)**

**(2002/733/EC)**

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**COMMISSION DECISION****of 30 May 2002****concerning the technical specification for interoperability relating to the energy subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC***(notified under document number C(2002) 1949)***(Text with EEA relevance)****(2002/733/EC)**

THE COMMISSION OF THE EUROPEAN COMMUNITIES,

Having regard to the Treaty establishing the European Community,

Having regard to Council Directive 96/48/EC of 23 July 1996 on the interoperability of the trans-European high-speed rail network <sup>(1)</sup>, and in particular Article 6(1) thereof,

Whereas:

- (1) In accordance with Article 2(c) of Directive 96/48/EC, the trans-European high-speed rail system is subdivided into structural or functional subsystems. These subsystems are described in Annex II to the Directive.
- (2) In accordance with Article 5(1) of the Directive, each of the subsystems shall be covered by a technical specification for interoperability (TSI).
- (3) In accordance with Article 6(1) of the Directive, draft TSIs shall be drawn up by the joint representative body.
- (4) The Committee set up under Article 21 of Directive 96/48/EC has appointed the European Association for Railway Interoperability (AEIF) as the joint representative body in accordance with Article 2(h) of the Directive.
- (5) The AEIF has been given a mandate to draw up a draft TSI for the energy subsystem in accordance with Article 6(1) of the Directive. This mandate has been established in accordance with the procedure laid down in Article 21(2) of the Directive.
- (6) The AEIF has drawn up the draft TSI, together with an introductory report containing a cost-benefit analysis as provided for in Article 6(3) of the Directive.
- (7) The draft TSI has been examined by the representatives of the Member States, in the framework of the Committee set up by the Directive, in the light of the introductory report.

<sup>(1)</sup> OJ L 235, 17.9.1996, p. 6.

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- (8) As specified in Article 1 of Directive 96/48/EC, the conditions for achieving interoperability of the trans-European high-speed rail system concern the design, construction, upgrading and operation of the infrastructures and rolling stock contributing to the functioning of the system to be put into service after the date of entry into force of the Directive. With regard to the infrastructures and rolling stock already in service at the time of entry into force of this TSI, the TSI should be applied from the time when work is envisaged on these infrastructures. However, the degree to which the TSI is applied will vary according to the scope and extent of the works foreseen and the costs and the benefits generated by the intended applications. In order for such partial works to concur into achieving full interoperability, they need to be underpinned by a coherent implementation strategy. In this context, a distinction should be made between upgrading, renewal and maintenance-related replacement.
- (9) It is recognised that Directive 96/48/EC and the TSIs do not apply to renewals or maintenance-related replacement. It is desirable however that the TSIs should apply to renewals — as will be the case for the TSIs for the conventional rail system under Directive 2001/16/EC. In the absence of a mandatory requirement and taking into account the extent of the renewal work, Member States are encouraged, where they are able to do so, to apply the TSIs to renewals and maintenance-related replacement.
- (10) In its current version, the TSI, which is the subject of this Decision, covers features specific to the high-speed system; as a general rule, it does not address the common aspects of the high-speed and conventional rail system. The interoperability of the latter is the subject of another directive<sup>(1)</sup>. Given that verification of interoperability has to be established by reference to the TSIs, in accordance with Article 16(2) of Directive 96/48/EC, it is necessary, during the transition period between the publication of this Decision and the publication of the Decisions adopting the ‘conventional rail’ TSIs, to lay down the conditions to be complied with in addition to the TSI attached. For these reasons it is necessary that each Member State inform the other Member States and the Commission of the relevant national technical rules in use for achieving interoperability and meeting the essential requirements of Directive 96/48/EC. In addition, those rules being national, it is necessary that each Member State inform the other Member States and the Commission of the bodies it appoints for carrying out the procedure for the assessment of conformity or suitability for use as well as the checking procedure in use for verifying the interoperability of subsystems within the meaning of Article 16(2) of Directive 96/48/EC. Member States shall apply, as far as possible, the principles and criteria provided for in Directive 96/48/EC for the implementation of Article 16(2) in the case of those national rules. As to the bodies in charge of those procedures, Member States will make use, as far as possible, of bodies notified under Article 20 of Directive 96/48/EC. The Commission will carry out an analysis of this information (national rules,

<sup>(1)</sup> Directive 2001/16/EC of the European Parliament and of the Council of 19 March 2001 on the interoperability of the trans-European conventional rail system (OJ L 110, 20.4.2001, p. 1).

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procedures, bodies in charge of implementing procedures, duration of these procedures) and, where appropriate, will discuss with the Committee the necessity of any measure to be taken.

- (11) The TSI, which is the subject of this Decision, does not impose the use of specific technologies or technical solutions except where this is strictly necessary for the interoperability of the trans-European high-speed rail network.
- (12) The TSI, which is the subject of this Decision, is based on best available expert knowledge at the time of preparation of the corresponding draft. Developments in technology or social requirements may make it necessary to amend or supplement this TSI. Where appropriate, a review or updating procedure will be initiated in accordance with Article 6(2) of Directive 96/48/EC.
- (13) In some cases, the TSI, which is the subject of this Decision, allows a choice between different solutions, making it possible to apply definitive or transitional interoperable solutions that are compatible with the existing situation. In addition, Directive 96/48/EC provides for special implementing provisions in certain specific cases. Furthermore, in the cases provided for in Article 7 of the Directive Member States must be allowed not to apply certain technical specifications. It is therefore necessary that the Member States ensure that an infrastructure register and a rolling stock register are published and updated each year. These registers will set out the main characteristics of the national infrastructure and rolling stock (e.g. the basic parameters) and their concordance with the characteristics prescribed by the applicable TSIs. To this end, the TSI, which is the subject of this Decision, indicates precisely which information must appear in the register.
- (14) The application of the TSI which is the subject of this Decision must take into account specific criteria relating to technical and operational compatibility between the infrastructures and the rolling stock to be placed in service and the network into which they are to be integrated. These compatibility requirements entail a complex technical and economical analysis that is to be done on a case-by-case basis. The analysis should take into account:

- the interfaces between the different subsystems referred to in Directive 96/48/EC,
- the different categories of lines and rolling stock referred to in that Directive and
- the technical and operational environments of the existing network.

That is why it is essential to establish a strategy for the implementation of the TSI which is the subject of this Decision, which should indicate technical stages to move from the present network conditions to a situation where the network is interoperable.

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- (15) The provisions of this Decision are in conformity with the opinion of the Committee set up by Directive 96/48/EC,

HAS ADOPTED THIS DECISION:

*Article 1*

The TSI relating to the ‘energy’ subsystem of the trans-European high-speed rail system referred to in Article 6(1) of Directive 96/48/EC is hereby adopted by the Commission. The TSI is set out in the Annex to this Decision. The TSI is fully applicable to the infrastructure and rolling stock of the trans-European high-speed rail system as defined in Annex I to Directive 96/48/EC, taking into account Article 2 and Article 3 hereunder.

*Article 2*

1. With regard to the aspects that are common to the high-speed and the conventional rail systems, but not covered in the attached TSI, the conditions to be complied with for the verification of the interoperability within the meaning of Article 16(2) of Directive 96/48/EC are the applicable technical rules in use in the Member State which authorises the placing in service of the subsystem concerned by this Decision.

2. Each Member State shall notify to the other Member States and to the Commission within six months of the notification of this Decision:

- the list of the applicable technical rules mentioned under Article 2(1),
- the conformity assessment and checking procedures to be applied with regard to the application of these rules,
- the bodies it appoints for carrying out those conformity assessment and checking procedures.

*Article 3*

1. For the purposes of this Article:

- ‘upgrading’ means major work to modify a subsystem or part of a subsystem which changes the performance of the subsystem,
- ‘renewal’ means major work to replace a subsystem or part of a subsystem which does not change the performance of the subsystem,
- ‘maintenance related replacement’ means replacement of components by parts of identical function and performances in the context of predictive or corrective maintenance.

2. In the case of upgrading, the contracting entity will submit a dossier describing the project to the Member State concerned. The Member State will examine the dossier and, taking into account the implementation strategy in Chapter 7 of the attached TSI, will (where appropriate) decide whether the scale of the work requires the need for a new authorisation for placing in service under Article 14 of Directive 96/48/EC. Such authorisation for placing in service is necessary whenever the level of safety may objectively be affected by the work envisaged.

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Where a new authorisation for placing in service under Article 14 of Directive 96/48/EC is necessary, the Member State decides whether:

- (a) the project includes full application of the TSI, in which case the subsystem will be subject to the EC verification procedure in Directive 96/48/EC; or
- (b) full application of the TSI is not yet possible. In this case the subsystem will not be in full conformity with the TSI and the EC verification procedure in Directive 96/48/EC shall be applied only in respect of the parts of the TSI applied.

In these two cases the Member State will inform the Committee set up pursuant to Directive 96/48/EC of the relevant dossier including the parts of TSI being applied and the degree of interoperability being achieved.

3. In the case of renewal and maintenance-related replacement, application of the attached TSI is voluntary.

*Article 4*

The relevant parts of Commission Recommendation 2001/290/EC <sup>(1)</sup> on the basic parameters of the trans-European high-speed rail system no longer have effect from the date of entry into force of the attached TSI.

*Article 5*

The attached TSI shall enter into force six months after notification of this Decision.

*Article 6*

This decision is addressed to the Member States

<sup>(1)</sup> OJ L 100, 11.4.2001, p. 17.

**▼B***ANNEX***TECHNICAL SPECIFICATION FOR INTEROPERABILITY RELATING  
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**▼B****1. INTRODUCTION****1.1. Technical scope**

This TSI concerns the energy subsystem, which is one of the subsystems listed in Annex II(1) to Directive 96/48/EC.

This TSI is part of a set of six TSIs, which cover all eight subsystems defined in the Directive. The specifications concerning the 'users' and 'environment' subsystems, which are necessary to ensure interoperability of the trans-European high-speed rail system in compliance with the essential requirements, are set out in the TSIs concerned.

More information about the energy subsystem is given in Chapter 2.

**1.2. Geographical scope**

The geographical scope of this TSI is the trans-European high-speed rail system as described in Annex I to Directive 96/48/EC.

Reference shall be made in particular to the lines of the trans-European rail network described in Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community guidelines for the development of the trans-European transport network or in any update to the same Decision as a result of the revision provided for in Article 21 of that Decision.

**1.3. Content of this TSI**

In accordance with Article 5(3) of and with Annex I(1)(b) to Directive 96/48/EC, this TSI:

- (a) specifies the essential requirements for the subsystems and their interfaces (Chapter 3);
- (b) establishes the basic parameters described in Annex II(3) to that Directive, which are necessary to meet the essential requirements (Chapter 4);
- (c) establishes the conditions to be complied with to achieve the specified performances for each of the following categories of line (Chapter 4):
  - category I: specially built high-speed lines equipped for speeds generally equal to or greater than 250 km/h,
  - category II: specially upgraded high-speed lines equipped for speeds of the order of 200 km/h,
  - category III: specially upgraded high-speed lines which have special features as a result of topographical, relief or town-planning constraints, on which the speed must be adapted to each case.
- (d) establishes implementing provisions in certain specific cases (Chapter 7);
- (e) determines the interoperability constituents and interfaces which must be covered by European specifications, including European standards, which are needed in order to achieve interoperability within the trans-European high-speed rail system while meeting the essential requirements (Chapter 5);

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- (f) states, in each case under consideration, which of the modules defined in Decision 93/465/EEC or, where appropriate, which specific procedures are to be used in order to assess either the conformity or the suitability for use of the interoperability constituents, as well as 'EC' verification of the subsystems (Chapter 6).

## 2. SUBSYSTEM DEFINITION/SCOPE

### 2.1. Scope

The energy subsystem of the trans-European high-speed rail system comprises all fixed installations that are required to supply, with respect to the essential requirements, the trains from high-voltage single-phase or three-phase networks.

The energy subsystem consists of:

- *substations*: they are connected on their primary side to the high-voltage grid with transformation of the high-voltage to a voltage and/or conversion to a power supply system suitable for the trains. On their secondary side substations are connected to the railway overhead contact lines,
- *sectioning points*: electrical equipment located at intermediate locations between substations to supply and parallel contact lines and provide protection, isolation, auxiliary supplies and compensation,
- *overhead contact lines*: the overhead contact lines distribute the energy to the trains running on the route and transmit it to the trains by means of pantographs. The overhead contact line is also equipped with manually or remotely controlled disconnectors which are required to isolate sections or groups of the overhead contact lines depending on the operational necessities. All types of feeder lines belong to the contact lines as well,
- *current return circuit*: the traction current utilises rails, which are connected directly or indirectly to earth, and return conductors, to flow back to the substations. Therefore, so far as this aspect is concerned, the current return circuit is part of the energy subsystem.
- *pantograph*: despite being installed on moving rolling stock the pantographs form an important device the proper function of which is directly linked to the overhead contact line. Therefore, it is considered to be part of the energy subsystem,

The following aspects of the energy subsystem are related to the interoperability of the trans-European high-speed rail system:

- electrification system,

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- overhead contact lines and pantographs,
- interaction of pantographs and overhead line equipment,
- boundaries between high-speed lines, upgraded lines and connecting lines.

**2.2. Definition of the subsystem****2.2.1. *Electrification system***

As with any electrical device a traction unit is designed in order to operate correctly with a nominal voltage and a nominal frequency applied at its terminals that are the pantographs and wheels. Variations and limits of these parameters need to be defined to guarantee the anticipated performance of the train.

High-speed trains need a correspondingly high power. Therefore, in order to supply the trains with minimum losses it is necessary to increase the voltage of the supply system and decrease the current that gives rise to the resistive losses. The power supply system has to be designed such that every train will be supplied with the necessary power. Therefore, the power consumption of each train and the operating schedule are important aspects for performance.

Modern trains use regenerative braking sending back energy to the power supply to reduce the overall power consumption. Therefore, the power supply system has to accept regenerative braking as well.

In any electrical system short-circuits and other fault conditions may occur. The electrification system needs to be designed such that the subsystem control detects these faults immediately and triggers measures to remove the short-circuit current and isolate the defect part of the circuit. After such events the electrification system has to be able to restore supply to all installations as soon as possible to resume operations.

**2.2.2. *Overhead contact line and pantograph***

From the interoperability point of view, the geometry of the overhead contact line equipment and of the pantographs is an important aspect. So far as the geometrical interaction is concerned the height of the contact wire above the rails, the lateral displacement in still air and under wind pressure and the contact force have to be specified. For the pantograph the geometry of the collector head is also fundamental in order to guarantee correct interaction with the contact line whilst taking into account the possible sway of the vehicles.

**2.2.3. *Interaction of overhead line and pantograph***

At the high speeds envisaged for the trans-European high-speed rail system the interaction of the overhead contact line and the pantograph represents a very important aspect in establishing a reliable power transmission without undue disturbances to railway installations and of the environment. This interaction is mainly determined by:

- static and aerodynamic efforts depending on the nature of the contact strip of the pantograph and the design of the pantographs,
- the compatibility of the contact strip material with the contact wire regarding limitation of wear on those components,

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- the dynamic behaviour and impacts on the current collection quality and the aim of a continuous, uninterrupted power supply without disturbances,
- the protection of the pantograph and overhead contact line equipment in case of a broken pantograph collector strip,
- the number of pantographs in service and the distance between them which have a fundamental impact on the collection quality since each pantograph can interfere with others on the same contact line.

#### 2.2.4. *Boundaries between high-speed lines and other lines*

High-speed lines have to be linked to upgraded lines or to connecting lines. The location of the boundaries between these types of line affects the power supply and contact line system and is, therefore, an aspect to be dealt with in the energy TSI.

### 2.3. **Links with other subsystems and within the subsystem**

#### 2.3.1. *Introduction*

The energy subsystem has many links with other subsystems of the trans-European high-speed rail system in order to achieve the envisaged performance of interoperability. These links are covered by the definition of interfaces and performance criteria.

#### 2.3.2. *Links concerning electrification system*

- Voltage and frequency and their permissible ranges interface with the rolling stock subsystem.
- The power installed on the lines and the specified power factor determine the performance of the interoperable high-speed rail system and interface with the rolling stock subsystem.
- Regenerative braking reduces energy consumption and interfaces with the rolling stock subsystem.
- Electrical fixed installations and on-board traction equipment need to be protected against short circuits by appropriate devices in substations. Tripping of circuit breakers in substations and on trains has to be coordinated; that is why electric protection interfaces with the rolling stock subsystem.
- Electric interference and harmonic emissions interface with the rolling stock and control-command and signalling subsystems.

#### 2.3.3. *Links concerning overhead contact line equipment and pantographs*

- In the case of high-speed lines the contact wire height needs special attention in order to avoid excessive wear of the contact wire. The contact wire height interfaces with the infrastructure and rolling stock subsystems.

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- To pass boundaries of electrification systems without bridging differing systems the number and arrangement of pantographs on trains have to be stipulated. They interface with the rolling stock subsystem.

- The possible sway of vehicles and pantographs interfaces with the rolling stock and infrastructure subsystems.

#### 2.3.4. *Links concerning interaction of overhead line and pantograph*

- The quality of current collection depends on the number of pantographs in service and their spacing. The arrangement of pantographs interfaces with the rolling stock subsystem.

### 3. **ESSENTIAL REQUIREMENTS**

#### 3.1. **Compliance with essential requirements**

According to Article 4(1) of Directive 96/48/EC the trans-European high-speed rail system, its subsystems and its interoperability constituents shall meet the essential requirements set out in general terms in Annex III to the Directive.

#### 3.2. **Aspects of essential requirements**

The essential requirements cover:

- safety,
- reliability and availability,
- health,
- environmental protection,
- technical compatibility.

According to Directive 96/48/EC the essential requirements may be generally applicable to the whole trans-European high-speed rail system or be specific to each subsystem and its constituents.

#### 3.3. **Specific aspects for the energy subsystem**

##### 3.3.1. ***Safety***

According to Annex III to Directive 96/48/EC essential requirements for the energy subsystem as far as safety is concerned are the following.

- 1.1.1. *The design, construction or assembly, maintenance and monitoring of safety-critical components, and more particularly of the components involved in train movement must be such as to guarantee safety at the level corresponding to the aims laid down for the network, including those for specific degraded situations.*
- 1.1.2. *The parameters involved in the wheel/rail contact must meet the stability requirements needed in order to guarantee safe movement at the maximum authorised speed.*
- 1.1.3. *The components used must withstand any normal or exceptional stress that has been specified during their period in service. The safety repercussion of any accidental failure must be limited by appropriate means.*

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1.1.4. *The design of fixed installations and rolling stock and the choice of the materials used must be aimed at limiting the generation, propagation and effects of fire and smoke in the event of a fire.*

1.1.5. *Any devices intended to be handled by users must be so designed as not to impair their safety if used foreseeable in a manner not in accordance with the posted instructions.*

The aspects mentioned under 1.1.2 and 1.1.5 are not relevant in case of the energy subsystem.

In order to satisfy the essential requirements 1.1.1, 1.1.3 and 1.1.4 above, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.2.2.2, 4.2.3.3, 4.3.1.2, 4.3.1.8, 4.3.2.1, 4.3.2.2 and 4.3.2.4 of Chapter 4 are met and the interoperability constituents used comply with the requirements set out in points 5.3.1.1, 5.3.2.1, 5.3.2.4 and 5.3.3.2 of Chapter 5. The essential requirements are met if compliance with the stipulations of Chapters 4 and 5 is verified.

The following essential requirements for safety according to Annex III to Directive 96/48/EC are especially of concern for the energy subsystem.

2.2.1. *Operation of the energy supply systems must not impair the safety either of high-speed trains or persons (users, operating staff, trackside dwellers and third parties).*

In order to satisfy the essential requirement 2.2.1 above, the Energy subsystem shall be designed and constructed so that the requirements set out in points 4.1.1, 4.2.2.2, 4.2.2.3, 4.2.2.7, 4.2.2.9, 4.3.1.2, 4.3.1.5, 4.3.1.7, 4.3.2.1, 4.3.2.2 and 4.3.2.4 of Chapter 4 are met and the interoperability constituents used comply with the requirements set out in point 5.3.1.1 of Chapter 5. The essential requirements are met if compliance with the stipulations of Chapters 4 and 5 is verified.

### 3.3.2. ***Reliability, availability and maintainability***

According to Annex III to Directive 96/48/EC, essential requirements for the energy subsystem as far as reliability, availability and maintainability are concerned are the following.

1.2. *The monitoring and maintenance of fixed or moveable components that are involved in train movements must be organised, carried out and quantified in such a manner as to maintain their operation under the intended conditions.*

In order to satisfy the essential requirement 1.2, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.3.1.9 and 4.3.2.6 of Chapter 4 are met. The essential requirements are met if compliance with the stipulations of Chapter 4 is verified.

**▼B****3.3.3. Health**

According to Annex III to Directive 96/48/EC essential requirements for the energy subsystem as far as health is concerned are the following.

1.3.1. *Materials likely, by virtue of the way they are used, to constitute a health hazard to those having access to them must not be used in trains and railway infrastructures.*

1.3.2. *Those materials must be selected, deployed and used in such a way as to restrict the emission of harmful and dangerous fumes or gases, particular in the event of fire.*

In order to satisfy the essential requirements 1.3.1 and 1.3.2, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.2.2.2, 4.2.3.2, 4.2.3.3, 4.3.1.2, 4.3.1.8, 4.3.1.10, 4.3.2.2 and 4.3.2.4 of Chapter 4 are met and the interoperability constituents used comply with the requirements set out in point 5.3.3.2 of Chapter 5. The essential requirements are met if compliance with the stipulations of Chapters 4 and 5 is verified.

**3.3.4. Environmental protection**

According to Annex III to Directive 96/48/EC essential requirements for the energy subsystem as far as environmental protection is concerned are the following.

1.4.1. *The repercussions on the environment of the establishment and operation of the trans-European high-speed rail system must be assessed and taken into account at the design stage of the system in accordance with the Community provisions in force.*

1.4.2. *The materials used in trains and infrastructure must prevent the emissions of fumes and gases which are harmful and dangerous to the environment, particularly in the event of fire.*

1.4.3. *The rolling stock and energy supply systems must be designed and manufactured in such a way as to be electromagnetically compatible with the installation equipment and public or private networks with which they might interfere.*

The aspects mentioned under 1.4.2 are not relevant in case of the energy subsystem.

In order to satisfy essential requirements 1.4.1 and 1.4.3, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.2.3.2, 4.2.3.3 and 4.3.1.5 of Chapter 4 are met. The essential requirements are met if compliance with the stipulations of Chapter 4 is verified.

The following essential requirement for environmental protection according to Annex III to Directive 96/48/EC are especially of concern for the energy subsystem.

2.2.2. *The functioning of the energy supply systems must not interfere with the environment beyond specified limits.*

In order to satisfy essential requirement 2.2.2, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.2.3.2 and 4.3.1.5 of Chapter 4 are met. The essential requirements are met if compliance with the stipulations of Chapter 4 is verified.



**▼B****3.3.5. Technical compatibility**

According to Annex III to Directive 96/48/EC essential requirements for the energy subsystem as far as technical compatibility is concerned are the following.

*1.5. The technical characteristics of the infrastructures and fixed installations must be compatible with each other and with those of the trains on the trans-European high-speed rail system.*

*If adherence to these characteristics proves difficult on certain sections of the network temporary solutions that ensure compatibility in the future may be implemented.*

In order to satisfy the essential requirement 1.5, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.1.1, 4.1.2, 4.2.2.1, 4.2.2.3, 4.2.2.4, 4.2.2.5, 4.2.2.6, 4.2.2.7, 4.2.2.8, 4.2.2.9, 4.2.2.10, 4.2.2.11, 4.2.2.12, 4.3.1.1, 4.3.1.3, 4.3.1.4, 4.3.2.1, 4.3.2.3, 4.3.2.5 and 4.3.3 of Chapter 4 are met and the interoperability constituents used comply with the requirements set out in points 5.3.1.2, 5.3.1.3, 5.3.1.4, 5.3.1.5, 5.3.1.6, 5.3.1.8, 5.3.2.2, 5.3.2.3, 5.3.2.4, 5.3.2.5, 5.3.2.6, 5.3.2.7, 5.3.2.9, 5.3.3.1, 5.3.3.2, 5.3.3.3 and 5.3.3.4 of Chapter 5 are met. The essential requirements are met if compliance with the stipulations of Chapters 4 and 5 is verified.

The following essential requirements for technical compatibility according to Annex III to Directive 96/48/EC are especially of concern for the energy subsystem.

*2.2.3. The electrical supply systems used throughout the trans-European high-speed rail system must:*

- *enable trains to achieve the specified performance levels,*
- *be compatible with the collection devices fitted to the trains.*

In order to satisfy essential requirement 2.2.3, the energy subsystem shall be designed and constructed so that the requirements set out in points 4.1.1, 4.1.2.1, 4.1.2.2, 4.1.2.3, 4.3.1.1, 4.3.1.3, 4.3.2.1, 4.3.2.3 and 4.3.2.5 of Chapter 4 are met and the interoperability constituents used comply with the requirements set out in points 5.3.1.1, 5.3.1.2, 5.3.1.4, 5.3.2.1, 5.3.2.5, 5.3.3.1 and 5.3.3.5 of Chapter 5 are met. The essential requirements are met if compliance with the stipulations of Chapters 4 and 5 is verified.

**3.4. Verification of conformity**

Conformity of the energy subsystem and its constituents to the essential requirements shall be verified in accordance with the provisions of Directive 96/48/EC and the specifications presented in Chapter 6 and its related Annexes A to C to this TSI.

**4. CHARACTERISATION OF THE SUBSYSTEM**

The trans-European high-speed rail system, to which Directive 96/48/EC applies and of which the Energy subsystem is a part, is an integrated system which requires the basic parameters, interfaces and performances to be verified in particular so as to ensure that the system is interoperable and that the essential requirements are met.

**4.1. Basic parameters of the Energy subsystem****4.1.1. Voltage and frequency**

Train services need standardisation of the voltage and frequency values as stipulated for interoperability. Table 4.1 lists the voltages and frequencies applicable depending on the line category.

**▼B**

*Table 4.1*  
**Voltages and frequencies**

Voltage and frequency	Line category		
	Connecting lines	Upgraded lines	High-speed lines
AC 25 kV 50 Hz	X	X	X
AC 15 kV 16,7 Hz	X	X	( <sup>1</sup> )
DC 3 kV	X	X	( <sup>2</sup> )
DC 1,5 kV	X	X	—

- (<sup>1</sup>) In countries with networks currently electrified at AC 15 kV 16,7 Hz, this system can be used for new lines. The same system can also be applied in adjacent countries when it can be economically justified.
- (<sup>2</sup>) The DC 3 kV supply may be used in Italy and Spain for existing lines and new line sections operated at 250 km/h when electrification with AC 25 kV 50 Hz would create a risk of disturbing ground and on-board signalling equipment on an existing line located near the new line.

**▼M1**

The voltage at the terminals of the substation and at the pantograph shall comply with Annex N to this TSI. The frequency of the voltage shall comply with Annex N to this TSI. For conformity assessment, see Annex N4.

**▼B**

#### 4.1.2. *Overhead line and pantograph*

On future high-speed, upgraded and connecting lines there should be only one type of current collector head used for all trains running on these lines. To implement this approach, all future high-speed trains will use pantographs with a 1 600 mm pantograph collector head. All newly built AC high-speed overhead line equipment shall comply with points 4.1.2.1 and 4.1.2.3, respectively. This also concerns upgraded and connecting AC and DC lines.

##### 4.1.2.1. *Geometry of overhead contact line for AC systems*

The height of contact wire above the rails, the gradient of contact wire in relation to the track and the lateral deflection of the contact wire under the action of a cross wind all govern the interoperability of the high-speed network. The permissible data are given in Table 4.2.

*Table 4.2*  
**Geometry of overhead contact lines for AC systems**

No	Description	Connecting lines	Upgraded lines	High-speed lines
1	Nominal height of contact wire (mm)	Between 5 000 and 5 750 ( <sup>1</sup> ) ( <sup>2</sup> )	Between 5 000 and 5 500 ( <sup>1</sup> )	5 080 or 5 300
2	Permissible contact wire gradient in relation to the track and variation of gradient	EN 50119, version 2001, point 5.2.8.2		No planned gradients acceptable

**▼B**

No	Description	Connecting lines	Upgraded lines	High-speed lines
3	Permissible lateral deflection of the contact wire under action of cross wind (mm)	$\leq 400$		

(<sup>1</sup>) For connecting lines with mixed freight and passenger traffic, for the operation of trailers with oversized gauge the contact wire height may be higher provided the pantograph is suited to collect the current with the specified quality and the development of the pantograph is sufficient as specified in point 5.3.2.5.

(<sup>2</sup>) At level crossings the contact wire height shall be designed according to national directives.

► **M1** ◀

The overhead contact line geometry shall comply with the requirements set in Annex H.3.1 to this TSI.

#### 4.1.2.2. *Geometry of overhead contact line for DC systems*

The data determining the geometry of overhead contact line for DC systems within the trans-European interoperable rail network is stipulated in Table 4.3.

Table 4.3

#### Geometry of overhead contact lines for DC systems

No	Description	Connecting lines	Upgraded lines
1	Nominal height of contact wire (mm)	Between 5 000 and 5 600 ( <sup>1</sup> ) ( <sup>2</sup> ) ( <sup>3</sup> )	Between 5 000 and 5 500 ( <sup>3</sup> )
2	Permissible contact wire gradient in relation to the track and variation of gradient	EN 50119, version 2001, point 5.2.8.2	
3	Permissible lateral deflection of the contact wire under action of cross wind (mm)	$\leq 400$	

(<sup>1</sup>) For connecting lines with mixed freight and passenger traffic, for the operation of trailers with oversized gauge the contact wire height may be higher provided the pantograph is suited to collect the current with the specified quality and the development of the pantograph is sufficient as specified in point 5.3.2.5.

(<sup>2</sup>) At level crossings the contact wire height shall be designed according to national directives.

(<sup>3</sup>) For the lines in Italy referred to in note 2 to Table 4.1 the contact wire height is between 5 000 mm and 5 300 mm. The other values apply to other types of lines.

► **M1** ◀

The overhead contact line geometry shall comply with requirements set in Annex (J.3.1) to this TSI.

#### 4.1.2.3. *Geometry of the pantograph collector head*

The width and the working range of the pantograph collector head, the width of the contact strips and the profile of the collector head are defined to achieve interoperability. Table 4.4 specifies data for both AC and DC systems. The profile of the pantograph collector head is depicted in figure 4.1.

▼ **B**

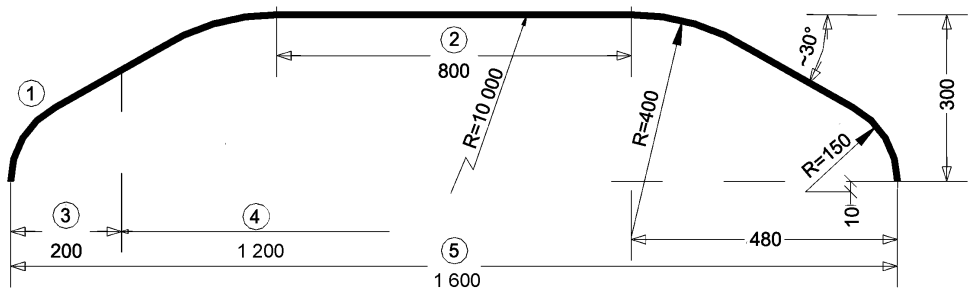
Table 4.4

**Geometry of pantograph collector head for AC and DC systems**

No	Description	All line categories
1	Width of pantograph collector head (mm)	1 600
2	Profile of pantograph collector head	See figure 4.1
3	Other requirements for AC systems	See Annex H(3)(2) to this TSI
4	Other requirements for DC systems	See Annex J(3)(2) to this TSI

Figure 4.1

**Profile of pantograph collector head**



- 1 Horn made of insulating material
- 2 Minimum length of the contact strip
- 3 Projected length
- 4 Working range of the collector head
- 5 Width of the collector head

**4.2. Interfaces of the energy subsystem**

**4.2.1. List of interfaces**

**4.2.1.1. Interfaces with Infrastructure**

- Gauges
- Protection against electric shock (earthing and bonding)

**4.2.1.2. Interfaces with Control-Command and Signalling**

- Harmonic currents, influence on signalling and internal telecommunications
- Control signals needed for phase and system separation sections

**4.2.1.3. Interfaces with Rolling Stock**

- Vehicle dynamic envelope
- Limitation of maximum power consumption
- Current at standstill

**▼B**

- Voltage and frequency
- Electrical protection coordination
- Arrangement of pantographs
- Running through phase separation sections
- Running through system separation sections
- Adjustment of pantograph contact force

4.2.1.4. *Common performance criteria with rolling stock*

- Power factor
- Regenerative braking
- Harmonic characteristics and related overvoltages on the overhead contact line

4.2.2. *Characteristic data of interfaces*4.2.2.1. *Gauges*

The infrastructure gauge shall take into account the space necessary for the passage of pantographs in contact with the overhead contact line equipment and for installation of the contact line equipment itself. The dimensions of tunnels and other structures shall be mutually compatible with the geometry of overhead line equipment and the dynamic envelope of the pantograph. (Annex (H.3.6) to this TSI specifies the dynamic envelope of the pantograph). The space necessary for installation of the contact line equipment shall be stipulated by the adjudicating entity. Conformity assessment shall be carried out within assessment of the Infrastructure subsystem.

4.2.2.2. *Earthing and bonding, protection against electric shock*

Infrastructure subsystem shall implement a general earthing system along the route to comply with the requirements for protection against electric shock specified in EN 50 122—1. Protection against electric shock during operation and in failure conditions is met by limiting touch voltages to acceptable limits as stipulated in EN 50 122-1, version 1997, point 7. Results of investigations carried out by the adjudicating entity and the corresponding specific provisions shall be provided to demonstrate the compliance with the requirements. Conformity assessment shall be carried out within the assessment of infrastructure subsystem.

4.2.2.3. *Harmonic currents, influence on signalling and internal telecommunications*

Harmonic currents generated by rolling stock affect the control-command and signalling subsystem through the energy subsystem. That is why this subject is dealt within the control-command and signalling subsystem. No conformity assessment is required by the energy subsystem.

**▼M1**4.2.2.4. *Vehicle dynamic envelope*

Overhead line equipment design shall comply with the dynamic envelope of the vehicle. The gauge to be adopted depends on the category of line. Conformity assessment shall be carried out within the energy subsystem.

**▼ M1**4.2.2.5. *Limitation of maximum power consumption*

The installed power on a high-speed line and upgraded or a connecting line determines the permissible power consumption of trains. Therefore, current limitation devices shall be installed on board as described in Annex O to this TSI. Assessment shall be carried out within assessment of the rolling stock subsystem.

**▼ B**4.2.2.6. *Limitation of current drawn by trains at standstill*

In case of DC 1,5 kV and 3,0 kV systems the current at standstill shall be limited to 300 A and 200 A, respectively, per pantograph. Assessment shall be carried out within assessment of the rolling stock subsystem.

4.2.2.7. *Voltage and frequency*

Trains shall be able to operate within the range of voltages and frequencies as given in point 4.1.1 and specified in Annex N to this TSI. Conformity assessment shall be carried out within assessment of the rolling stock subsystem.

4.2.2.8. *Electrical protection coordination***▼ M1**

Coordination between the electrical protection of substations and that of traction units is necessary to optimise the clearance of short-circuits. (Annex E to this TSI gives the applicable requirements.).

**▼ B**

Conformity assessment shall be carried out with the energy subsystem in so far as design and operation of substation is concerned and with the rolling stock subsystem in so far as equipment on traction units is concerned.

4.2.2.9. *Arrangement of pantographs*

The arrangement of pantographs on trains shall take care of the maximum train length. The maximum distance between pantographs is less than 400 m. In addition the spacing between three consecutive pantographs shall be more than 143 m. The acceptable number of pantographs and their spacing depend also on the dynamic performance. The pantographs shall not be linked electrically in case of AC power supply systems. Reference is made to Annex H (H.3.5) to this TSI.

Conformity assessment shall be carried out with the rolling stock subsystem.

4.2.2.10. *Running through phase separation sections*

Trains shall be able to move from one section to an adjacent one without bridging the two phases.

Adequate means shall be provided to allow a train that is stopped underneath the phase separation to be restarted. For design, reference is made to Annex H(H.3.3), to this TSI.

**▼ M1****▼ B**

Power consumption (traction and auxiliaries) of the train shall be brought to zero when entering the phase separation section. This shall be done automatically without the driver's intervention. Lowering of the pantographs is not necessary.

**Requirements for design of energy subsystem**

**▼ B**

*For future lines* two types of designs of phase separation sections may be adopted:

- a phase separation design where all the pantographs of the longest interoperable trains are inside the neutral section. In this case there is no restriction for the arrangement and spacing of the pantographs on the trains. The length of the neutral section shall be at least 402 m. For detailed requirements see Annex H(H.3.3) to this TSI,
- a shorter phase separation with a restriction for pantograph arrangement on trains is shown in Annex H(H.3.3) to this TSI. The overall length of this separation is less than 142 m. Using this design necessitates that the distance between three consecutive pantographs in service is more than 143 m.

*For existing lines* various solutions might be adopted and based on the accepted arrangement of pantographs on the train, depending on the possibilities of route planning, required performance and investments acceptable to the adjudicating entity. If the design of existing phase separations does not permit the passage of interoperable high-speed trains, then the adjudicating entity shall provide adequate alternative procedures or designs.

**▼ M1****▼ B**

For design of phase separation section, conformity assessment shall be carried out within assessment of the energy subsystem.

#### **Requirements for control-command and rolling stock subsystems**

On high-speed lines, the control-command and signalling subsystem shall allow the rolling stock to operate automatically before and after phase separation sections. Equipment on traction units shall be triggered in due time in front of a phase separation section taking full account of the maximum permissible running speed. For conformity assessment functional tests shall be carried out jointly with rolling stock and control-command and signalling subsystems.

#### **4.2.2.11. *Running through system separation sections***

##### *General*

Trains shall be able to move from one energy supply system to an adjacent one that uses a different energy supply without bridging the two systems. The necessary actions depend on the type of both supply systems as well as on the arrangement of pantographs on trains and the running speed.

There are two possibilities for the train to run through system separation sections:

- (1) with pantograph raised and touching the contact wire,
- (2) with pantograph lowered and not touching the contact wire.

**▼ M1**

A choice has to be made by the adjudicating entity.

**▼ B****Requirements for the design of energy subsystem***— Pantographs raised*

If system separation sections are negotiated with pantographs raised to the contact wire the following conditions apply:

- (1) the functional design of the system separation section is specified as follows:
  - the geometry of different elements of the overhead contact line shall prevent pantographs short-circuiting or bridging both power systems with the arrangement of pantographs specified in point 4.2.2.9,
  - for short neutral section, the mechanical behaviour of the pantograph overhead contact line system shall comply with the EN 50 119, version 2001, point 5.2, at maximum speed,
  - provisions shall be taken in the energy subsystem to avoid bridging of both adjacent power supply systems when the opening of the on-board circuit breaker(s) fails,
  - an example for arrangement of system separation section is given in figure H.4 of Annex H to this TSI;
- (2) the height of the contact wires in both systems has to be the same, if the speed is more than 250 km/h. Details and tolerances are given in Annexes H and J to this TSI;
- (3) on rolling stock, devices shall open automatically the circuit breaker before reaching the separation section and recognise automatically the voltage of the new power supply system at the pantograph in order to switch the corresponding circuits.

*— Pantographs lowered*

If the system separation sections are negotiated with pantographs down the following conditions apply:

- (1) the design of the separation section between differing energy supply systems shall ensure that, in case of an unintentional pantograph at the contact line, bridging of the two power supply systems is avoided and switching off both supply sections is triggered immediately. Triggering of a short circuit ensures operation of insulated sections;
- (2) this alternative choice has to be made if the conditions of operation with pantographs raised are not complied with;
- (3) on high-speed lines with different heights of contact wire and on separation sections of existing lines not complying with the TSI requirements, pantographs shall be lowered when the energy supply system changes or when the running speed does not permit the installation of transition sections with acceptable gradients (see Annexes H and J to this TSI);
- (4) at supply system separations which require a lowering of the pantograph, the pantograph shall be lowered without the driver's intervention, triggered by control signals.



**▼ B**

For design of system separation sections conformity assessment shall be carried out within the energy subsystem.

**Requirements for control-command and rolling stock subsystems**

Before running through separation sections between different energy supply systems the traction units' main circuit breaker shall be opened without the driver's intervention, triggered by control signals. This shall be carried out in good time so that the traction unit electrical equipment for the terminating energy supply system fully shuts down before the new energy supply system is reached.

The control-command and signalling subsystem shall provide the required signals to the traction units.

The traction units shall be designed so that they are able to receive line control signals to trigger the opening of the main circuit breaker and lower the pantographs if required without the driver's intervention. When pantographs are not lowered from the contact wire, only those electric circuits on the traction units which instantaneously conform to the energy supply system at the pantograph may remain connected.

**▼ M1****▼ B**

Conformity assessment shall be carried out with functional tests jointly with control-command and rolling stock subsystems.

4.2.2.12. *Adjustment of pantograph contact force*

Rolling stock shall permit by internal controls adjustment of pantograph contact force to comply with the requirements specified in point 5.3.2.7. Conformity assessment shall be carried out within the rolling stock subsystem.

4.2.3. ***Regulatory and operational provisions***4.2.3.1. *General regulatory conditions*

To guarantee the coherence of the trans-European high-speed rail system the following regulatory and operational provisions apply.

4.2.3.2. *Protection of the environment*

Protection of the environment is covered by Council Directive 85/337/EEC concerning the assessment of the effects of certain projects on the environment.

Specific requirements are not necessary for the energy subsystem of interoperable high-speed lines.

4.2.3.3. *Fire protection*

Fire protection is covered by Directive 89/106/EEC and its interpretative document concerning essential safety requirement No 2, 'Fire Safety'.

Specific requirements are not necessary for the Energy subsystem of interoperable high-speed lines.

**▼ B**4.2.3.4. *Exception in the case of execution of works*

The specifications for the energy subsystem and its interoperability constituents defined in Chapters 4 and 5 of the TSI are applicable to lines in normal functioning conditions or in the case of unexpected malfunctions which require the application of the maintenance plan.

Under some situations where works have been programmed in advance, it may not be possible to conform to these provisions whilst executing modifications to the Energy subsystem.

These temporary exceptions to the TSI rules shall be defined by the adjudicating entity of the line concerned, who shall be careful that no risks for the safety of passing trains will result therefrom, by applying the following general provisions:

- the exceptions allowed shall be temporary and planned for a specific time period,

**▼ M1**

- railway undertakings operating on the line shall be given notice of these temporary exceptions, of their geographic situation, of their nature and of their particular signalling, by means of written notices describing the case being the type of specific signals used,

**▼ B**

- any exception shall induce complementary safety measures, so as to ensure that the safety level requirement stays fulfilled. These complementary measures may in particular consist of:

- particular survey provisions of the works concerned,
- temporary speed restrictions on the line section as taken by the adjudicating entity.

**▼ M1****▼ B**4.3. **Specified performance**4.3.1. ***Performance of power supply system, substations and posts***4.3.1.1. ***Installed power***

The performance to be achieved by the energy subsystem shall correspond to the relevant specified performance for each category of lines in the trans-European high-speed rail network system in respect of:

- the maximum line speed,
- the peak power at the pantographs and drawn by the trains,
- the minimum headway,
- the mean useful voltage.

**▼ M1**

The adjudicating entity shall declare the type of the line depending on its function with reference to Annex F to this TSI. Electrification system design shall guarantee the ability of the power supply to achieve the specified performance. Therefore, clause 4.2.2.5 gives a requirement on limitation of power consumption by rolling stock subsystem.

**▼ B**

The calculated mean useful voltage at the pantograph shall comply with Annex L to this TSI.

**▼B**4.3.1.2. *Safety, earthing and bonding*

Safety of energy supply system, substations and posts shall be achieved by designing and testing these installations according to EN 50 122-1, version 1997, points 5, 7 and 9. Substations and posts shall be barred against unauthorised access.

4.3.1.3. *Power factor*

The acceptable data for power factor is stipulated in Annex G to this TSI. On high-speed lines the minimum value is 0,95 under the conditions described in the abovementioned document. Conformity assessment to be carried out within assessment of the rolling stock subsystem.

4.3.1.4. *Regenerative braking*

The AC energy supply systems shall be designed to permit the use of regenerative braking as a service brake able to exchange power seamlessly with other trains or with the primary network supplier. Reference is made to Annex K to this TSI.

Train equipment shall allow the use of other braking systems where regenerative braking is not possible.

**▼M1**

The adjudicating entity can decide whether or not to accept regenerative braking on DC systems.

**▼B**

Conformity assessment for fixed installations shall be carried out as specified in Annex K(K.4) to this TSI.

For rolling stock conformity assessment shall be carried out as specified in the rolling stock TSI.

4.3.1.5. *External electromagnetic compatibility*

External electromagnetic compatibility is not a specific characteristic of the trans-European high-speed rail network. Energy supply installations shall comply with the standards EN 50 121-2 and EN 50 122 series to meet all requirements concerning electromagnetic compatibility. No conformity assessment is required within this TSI.

4.3.1.6. *Harmonic emissions towards the power utility*

Concerning harmonic emissions towards the power utility it is up to the adjudicating entity to comply with the national standards (or European standards when available) and with the requirements of the power utility. No conformity assessment is required within this TSI.

4.3.1.7. *Harmonic characteristics and related overvoltages on the overhead contact line*

To avoid unacceptable overvoltages on the overhead contact line caused by harmonics generated by motive power units the motive power units shall comply with Annex P to this TSI. The necessary requirements are defined in the rolling stock subsystem and conformity assessment shall be carried out with the rolling stock subsystem, as defined in Annex P.

**▼B****4.3.1.8. *Protection against electric shock***

The energy supply system shall be integrated into the general earthing system along the line to comply with the requirements for protection against electric shock as specified in EN 50 122-1, version 1997, points 5, 7 and 9. Protection against electric shock during operation and in failure conditions is met by limiting touch voltages to acceptable limits as stipulated in EN 50 122-1, version 1997, points 7.2 and 7.3. For each installation a study shall be established to prove the protection against electric shock. The study may include tests.

**4.3.1.9. *Maintenance plan***

A maintenance plan shall be drawn up by the adjudicating entity or his authorised representative to guarantee that the specified characteristics of the energy subsystem are upheld within the limits specified for them.

The maintenance plan shall contain at least the following elements:

- maintenance routines in substations and posts,
- recording of conditions, findings and experience gained,
- a set of safety limit values which would lead to a limitation of train speeds in order to comply with the specifications in point 4.1.1,
- an indication of the frequencies of checks and of the tolerances on measured values with for latter an indication of the rules of equivalence with the values of the standard quoted in subsection 4.3.1,
- the measures taken (speed restriction, repair time) when prescribed values are exceeded.

Maintenance procedures should not downgrade safety provisions such as continuity of return current circuit, limitation of overvoltages and detection of short circuits. It shall not reduce the global performance of the system and avoid de-energising of any part of the overhead contact line.

**4.3.1.10. *Isolation of power supply in case of danger***

Equipment shall be installed and procedures implemented to initiate isolation of voltage from traction units and electrified lines through alarm devices allowing the power supply operator to carry out emergency actions. Conformity assessment shall be carried out by checking the transmission devices and instructions for procedures.

**4.3.1.11. *Continuation of power supply in case of disturbances***

The power supply and the overhead contact line shall be designed to enable continuation of operation in case of disturbances. This can be achieved by sectioning contact lines into supply sections and installation of redundant equipment in substations. Conformity assessment shall be carried out by checking the circuit diagrams.

**▼B****4.3.2. Performance of the overhead contact line****4.3.2.1. General**

The performance to be achieved by the overhead contact line shall correspond to the relevant performance as specified for each category of lines of the trans-European high-speed rail system in function of

- the maximum line speed, and
- the power demand of the trains at the pantographs.

The overhead contact line design shall guarantee the specified performance in accordance with the declaration made by the adjudicating entity in the frame of point 4.3.1.1.

**4.3.2.2. Safety, earthing and bonding**

The safety of the overhead contact line is achieved by designing these installations according to the European standards EN 50 119, version 2001, point 5.1.2 and EN 50 122-1, version 1997, points 5, 7 and 9. All live components shall be installed out of reach of users and any other persons.

**4.3.2.3. Requirements for dynamic behaviour and quality of current collection**

The design of the overhead line equipment shall comply with the requirements on the dynamic behaviour. The uplift under the design speed of the line shall comply with the stipulations in EN 50 119, version 2001, point 5.2.1.2 and on Tables 4.5 and 4.6 of this TSI.

The quality of current collection has a fundamental impact on the life of a contact wire and shall, therefore, comply with agreed and measurable parameters.

The collection quality may be assessed by the mean value  $F_m$  and the standard deviation  $\sigma$  of measured or simulated contact forces or by counting of arcing. For AC systems the criteria are listed in Table 4.5 and for DC systems in Table 4.6.

The adjudicating entity shall decide to use interaction criterion item No 1 (contact force) or item No 2 (arcing) according to Table 4.5 or 4.6.

The interaction is considered to comply with the provisions in this TSI if

- item 1 or 2 of Table 4.5, and
- item 3 of Table 4.5,

are fulfilled.

Test results from a similar overhead contact line system may be used as a basis for conformity assessment.

For the qualification of the performance with more than one pantograph, it shall be taken into account the pantograph which will show the more critical values.



Table 4.5

**Interaction requirements, AC systems**

No	Description	Connecting and upgraded lines	High-speed lines	
			Existing	New
1	Corrected mean force $F_m$ (N) <sup>(1)</sup>	See points 5.3.1.6 and 5.3.2.7 <sup>(2)</sup>		See point 5.3.1.6 <sup>(2)</sup>
	Standard deviation at maximum speed $\sigma_{max}$ (N)	0,3 $F_m$		
2	Percentage of arcing at maximum speed, NQ (%)	$\leq 0,14$		
3	Necessary space for maximum uplift of steady arm under adverse aerodynamic conditions	See EN 50119, version 2001 point 5.2.1.2	$2 \cdot S_0$ <sup>(3)</sup>	

For definitions, values and tests see Annex Q

<sup>(1)</sup>  $F_m$  is the dynamically corrected average value of the contact force obtained after statistical analysis of the results of contact force measurements or simulations.

<sup>(2)</sup> The dynamic correction shall be applied on the values given in points 5.3.1.6 and 5.3.2.7.

<sup>(3)</sup>  $S_0$  is the calculated, simulated or measured uplift of contact wire at the steady arm generated in normal operating condition with one or several pantographs with a mean contact force  $F_m$  at the maximum speed of the line, in accordance with EN 50 119 version 2001, point 5.2.1.2.

Table 4.6

**Interaction requirements, DC systems**

No	Description	Connecting and upgraded lines <sup>(1)</sup>
1	Corrected mean force $F_m$ (N) <sup>(2)</sup>	See points 5.3.1.6 and 5.3.2.7 <sup>(3)</sup>
	Standard deviation at maximum speed $\sigma_{max}$ (N)	0,3 $F_m$
2	Percentage of arcing at maximum speed, NQ (%)	$\leq 0,20$
3	Necessary space for maximum uplift of steady arm under adverse aerodynamic conditions	See EN 50119, version 2001 point 5.2.1.2 <sup>(4)</sup>

For definitions, values and tests see Annex Q

<sup>(1)</sup> For lines in Italy and Spain referred to note 2 to Table 4.1 the values specified for upgraded lines apply as well.

<sup>(2)</sup>  $F_m$  is the dynamically corrected average value of the contact force obtained after statistical analysis of the results of contact force measurements or simulations.

<sup>(3)</sup> The dynamic correction shall be applied on the values given in points 5.3.1.6 and 5.3.2.7.

<sup>(4)</sup> The necessary space is determined by the calculated, simulated or measured uplift of contact wire at the steady arm generated in normal operating condition with one or several pantographs with a mean contact force  $F_m$  at the maximum speed of the line.

**▼B****4.3.2.4. *Protection against electric shock***

The overhead contact line shall be integrated into the general earthing system along the line to comply with the requirements for protection against electric shock as specified in EN 50 122-1, version 1997, points 5, 7 and 9. Protection against electric shock during operation and in failure conditions is met by limiting touch voltages to acceptable limits as stipulated in EN 50 122-1, version 1997, points 7.2 and 7.3. For each installation a study shall be established to prove the protection against electric shock.

**4.3.2.5. *Static and mean aerodynamic contact force***

The nominal static force is specified by the adjudicating entity inside the following ranges:

- 70 N + 20 N/-10 N for AC supply systems,
- 110 N ± 10 N for DC 3 kV supply systems,
- 90 N ± 20 N for DC 1,5 kV supply systems.

In DC systems to improve the contact of carbon collector strips with the contact wire, a force more important, in general 140 N, can be required to avoid a hazardous heating of the contact wire when the train is at standstill with its auxiliaries working.

The value of total mean uplift force shall comply with the value of mean contact force  $F_m$  required for a good quality of current collection (see point 4.3.2.3, 5.3.1.6 and 5.3.2.7).

Conformity assessment is carried out by assessing the interoperable constituent 'pantograph'.

**4.3.2.6. *Maintenance plan***

A maintenance plan shall be drawn up by the adjudicating entity or his authorised representative to guarantee that the specified characteristics of the energy subsystem are upheld within the limits specified for them.

The maintenance plan shall contain at least the following elements:

- maintenance routines for overhead contact lines,
- recording of conditions, findings and experience gained,
- a set of safety limit values which would lead to a limitation of train speeds for the contact wire height and stagger according to points 4.1.2.2 and 4.1.2.3 of this TSI,
- an indication of the frequencies of checks and of the tolerances on measured values of the geometrical and dynamic data and of the means used to check them, with for latter an indication of the rules of equivalence with the values of the standard quoted in Subsection 4.3.2,
- the measures taken such as speed restriction and expected repair time when prescribed values are exceeded.

**▼B**

Maintenance procedures should not downgrade safety provisions such as continuity of return current circuit, limitation of overvoltages and detection of short circuits. It shall not reduce the global performance of the system.

#### 4.3.3. ***Boundaries between high-speed lines and other lines***

It is up to the adjudicating entity to define, on a short route section, which connects a high-speed line with another line, the location where the requirements of the energy subsystem TSI for high-speed lines apply and their specified performances will be met.

### 5. **INTEROPERABILITY CONSTITUENTS**

#### 5.1. **General**

According to Article 2(d) of Directive 96/48/EC interoperability constituents are:

*‘any elementary component, group of components, subassembly or complete assembly of equipment incorporated or intended to be incorporated into a subsystem, upon which the interoperability of the trans-European high-speed rail system depends either directly or indirectly’.*

The interoperability constituents are covered by the relevant provisions of Directive 96/48/EC and are listed in section 5.2 of this TSI so far as the Energy subsystem is concerned.

#### 5.2. **Definitions of interoperability constituents**

In case of the Energy subsystem the following constituents are defined:

- *overhead contact line*: an overhead contact line is a contact line placed above the upper limit of the vehicle gauge and supplying vehicles with electric energy through roof-mounted current collection equipment referred to as pantographs. In the case of high-speed rail systems overhead contact lines with catenary suspension are applied where the contact wire(s) is/are suspended from one or more longitudinal catenaries. The supporting components such as cantilevers, masts and foundations will not affect the interoperability and, therefore, are not covered by this TSI,
- *pantograph*: pantographs are devices for collecting currents from one or more contact wires formed by a hinged device designed to allow vertical movement of the pantograph head. The pantograph head carries the contact strips and their mountings. The end of the pantograph head is formed by a down-turned horn,
- *contact strips*: contact strips are the replaceable parts of the pantograph head which are in direct contact with the contact wire and as a consequence are prone to wear.

#### 5.3. **Characterisation of constituents**

##### 5.3.1. ***Overhead contact line***

###### 5.3.1.1. ***Overall design***

Design of overhead contact lines shall comply with EN 50 119, version 2001, points 5 and 6. Additional requirements, specially concerning high-speed lines are specified hereafter.

The overhead contact line shall meet the specified performance for the specific line especially so far as the maximum running speed and the current carrying capacity are concerned.



**▼B**5.3.1.2. *Current capacity***▼M1**

The current capacity depends on the ambient conditions which are maximum ambient temperature and minimum cross-wind speed as well as the permissible temperatures of the contact line elements and the duration of current action. The design of the overhead contact line shall take care of the limits for the maximum temperatures as specified in Annex B to EN 50 119, version 2001, taking account of the data given in EN 50 149, version 1999, point 4.5, Tables 3 and 4. An analysis shall prove that the contact line is able to comply with the specified requirements.

**▼B**5.3.1.3. *Basic parameters*

The design of the overhead contact line shall comply with the basic parameters as specified in points 4.1.2.1 and 4.1.2.2.

5.3.1.4. *Wave propagation speed*

The speed of wave propagation on contact wires is a characteristic parameter for assessing the suitability of a contact line for a high-speed operation. This parameter depends on the specific mass and the stress of the contact wire. Maximum operation speed shall not be more than 70 % of the wave propagation speed. See also EN 50 119, version 2001, point 5.2.1.4.

5.3.1.5. *Elasticity and uniformity of elasticity*

Elasticity and the uniformity along the span are essential for a high-quality current collection and a reduction of wear and tear. The uniformity of elasticity can be assessed by the uniformity factor  $u$

$$u = \frac{e_{\max} - e_{\min}}{e_{\max} + e_{\min}} \cdot 100 (\%).$$

where:

$e_{\max}$  maximum elasticity along a span,

$e_{\min}$  minimum elasticity along a span.

In case of high-speed lines a parameter  $u$  as low as possible should be aimed at; Table 5.1 gives limit values for  $u$ , which are accepted for each type of overhead contact line.

Table 5.1

**Uniformity  $u$  of elasticity in %**

Type of contact line	Running speed km/h		
	200 to 230	230 to 300	Above 300
Without stitch wire	< 40	< 40	< 25
With stitch wire	< 20	< 10	< 10

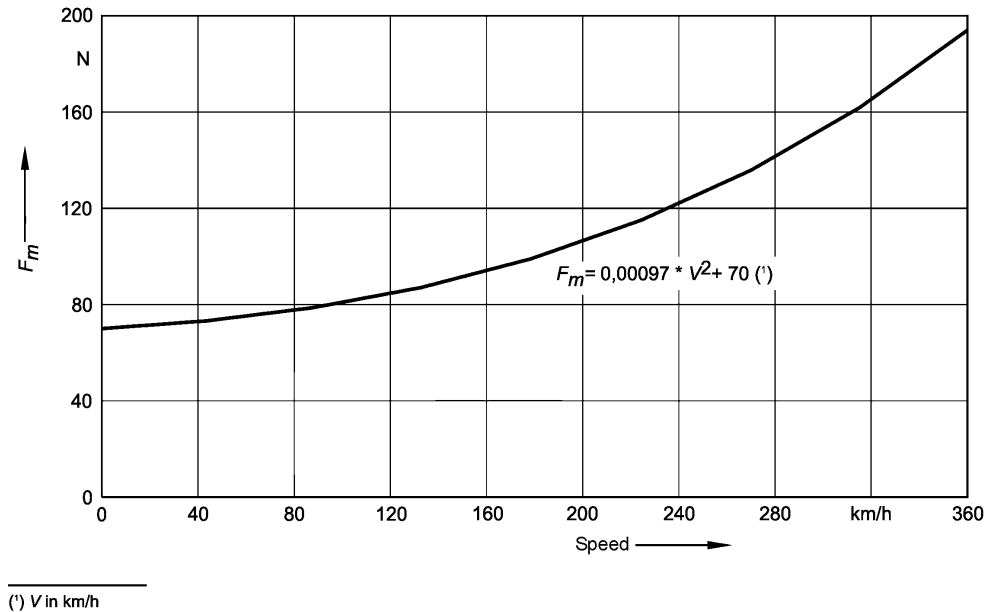
For high-speed lines the mid-span elasticity should be limited to values less than 0,5 mm/N. The contact line shall comply with EN 50 119, version 2001, point 5.2.1.3.

▼ **B**5.3.1.6. *Mean contact force*

This clause stipulates mean contact forces for which the contact line shall be designed.

Figure 5.1

**Target for mean contact force  $F_m$  for AC systems depending on running speed**



The mean contact force  $F_m$  formed by the static and aerodynamic components of the contact force with dynamic correction which shall be applied on the contact wire is shown in figure 5.1 for AC systems as a function of running speed.

In this context  $F_m$  represents a target value which should be achieved to ensure on one hand a current collection without undue arcing and which should not be exceeded on the other hand to limit wear and hazards to current collection strips.

In case of trains with multiple pantographs simultaneously in operation the mean contact force  $F_m$  for any pantograph shall be not higher than the value given by figure 5.1 since for each individual pantograph the current collection criteria shall be met.

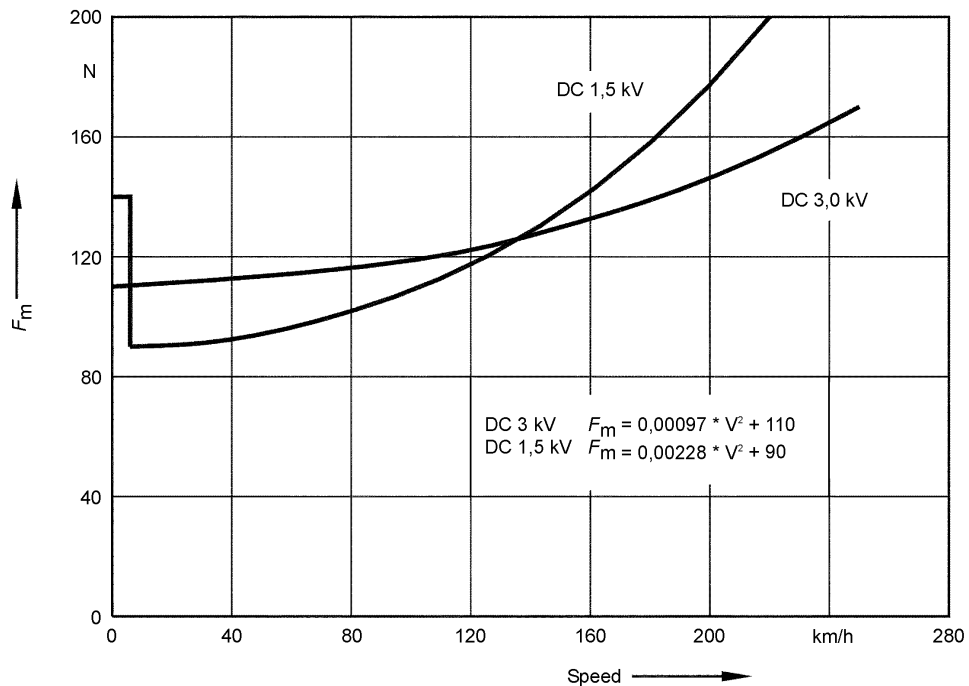
Concerning DC systems, the mean contact force  $F_m$  formed by the static and aerodynamic components of the contact force with dynamic correction which shall be applied for DC 1,5 kV and DC 3,0 kV systems is shown in fig. 5.2 as a function of running speed. For DC 1,5 kV lines the static contact force should be 140 N where necessary in respect of the current at standstill.

In case of trains with multiple pantographs simultaneously in operation the mean contact force  $F_m$  for any pantograph shall be not higher than the value given by figure 5.2 since for each individual pantograph the current collection criteria shall be met.



Figure 5.2

Target for mean contact force for  $F_m$  for DC 1,5 kV and DC 3,0 kV lines depending on the running speed



#### 5.3.1.7. Maintenance

The manufacturer shall provide any necessary information to allow the adjudicating entity to draft a plan concerning maintenance taking into account especially the geometry of the overhead line, the wear of the contact wire, especially at critical points such as crossings, switches and overlaps.

#### 5.3.1.8. Current at standstill

An acceptable level of current at standstill shall be acceptable for both the contact wire and pantograph collector strips to allow a proper feeding of the auxiliaries installed on board trains. For DC 1,5 kV systems a current of 300 A per pantograph shall be guaranteed, while for DC 3,0 kV systems a current of 200 A per pantograph shall be guaranteed. When testing the overhead contact line with the methodology specified in EN 50 206-1, version 1998, point 6.13, the contact wire temperature shall not exceed the limits given in Annex B to EN 50 119, version 2001.

### 5.3.2. Pantograph

#### 5.3.2.1. Overall design

The pantograph shall meet the specified performance as far as maximum running speed and current carrying capacity are concerned. So far as not specified hereafter EN 50 206 applies. The installation of pantograph on rolling stock is dealt with by the rolling stock subsystem.

#### 5.3.2.2. Basic parameters

The design of the pantograph shall meet the basic parameters as specified in section 4.1.

**▼B****5.3.2.3. *Current capacity***

The pantograph shall be designed for the specified current to be transmitted to the vehicles. The rated current shall be provided by the manufacturer. Attention shall be given especially to the specific data depending on the use on AC or DC systems. An analysis shall prove that the pantograph is able to carry the specified current.

**5.3.2.4. *Design of insulation***

The pantographs shall be assembled on the roof of the vehicles insulated against earth. The design of insulation shall take care of the stresses by voltage. References for data to be verified are in Annex N to this TSI for system voltages and EN 50 124-1, version 1999, Table 2, for insulation coordination requirements. Insulators shall be tested according to EN 60 383.

**5.3.2.5. *Working range of pantographs***

The pantographs shall be able to work under contact wire heights between 4 800 mm and 6 400 mm. For operation in the UK and Finland on upgraded or connecting lines, the height is different. See section 7.3.

**5.3.2.6. *Static contact force***

Static force is the mean vertical contact force exerted upward by the collector head on the contact line and caused by the pantograph raising device, whilst the pantograph is raised and the vehicle is at standstill.

For AC systems the static force shall be adjustable between 40 N and 120 N.

In DC systems to improve the contact of collector strips with the contact wire, a higher force may be needed to avoid dangerous heating of the contact wire when the train is at standstill with its auxiliaries working. For DC systems the static force shall be adjustable between 50 and 150 N.

The pantographs and their mechanisms that provide the necessary contact forces shall ensure that the pantographs can be used on every type of interoperable overhead contact line. For details and assessment reference is made to EN 50 206-1, version 1998, point 6.3.1

**5.3.2.7. *Mean contact force and interaction performance of the overhead line/pantograph system***

The mean contact force is the mean value of the forces due to static and aerodynamic actions. It is equal to the sum of static contact force (point 5.3.2.6) and the aerodynamic force caused by the airflow on the pantograph elements at the considered speed. The mean uplift force is a characteristic of the pantograph for given rolling stock and a given development of the pantograph. The mean contact force is measured at the collector head according to Annex Q(Q.4.2.2).

The value of mean contact force shall comply with the mean contact force  $F$  stipulated in point 5.3.1.6.

**▼B**

For existing, connecting, upgraded and high-speed AC lines which would not comply with the requirements stipulated in point 5.3.1.6, the pantograph shall be designed such that the running speed-dependent mean contact force  $F_m$ , in addition to the target curve according to figure 5.1, allows other adjustment curves C1 and C2.

These curves are defined in Annex Q(Q.4.1).

**▼M1**

The manufacturer of the pantograph shall provide for the change between the three curves to be made on board taking the appropriate information e.g. use of 1 950 mm pantograph or information on the type of voltage on the overhead contact line.

**▼B**

In case of trains with multiply pantographs simultaneously in operation, the contact force  $F_m$  for any pantograph shall not be higher than the value given by the target curve of point 5.3.1.6 or one of the curves C1 or C2 since for each individual pantograph the current collection criteria shall be met.

Those requirements are specified in Annex Q.

Assessment shall be carried out according Annex Q.

5.3.2.8. *Automatic dropping device*

Pantographs shall be equipped with a device that drops the pantograph in case of a failure according to EN 50 206-1, version 1998, point 4.9.

5.3.2.9. *Current at standstill*

The current drawn by the trains at standstill shall be acceptable for both the contact wire and pantograph collector strips to allow proper feeding of the auxiliaries installed on board trains. For DC systems, in order to be in accordance with point 5.3.1.8, a current of 300 A per pantograph shall be guaranteed. A study shall prove that the pantograph is able to carry the specified current at standstill.

For conformity assessment reference is made to EN 50 206-1, version 1998, point 6.13 and Annex Q.

5.3.3. **Contact strips**5.3.3.1. *Basic parameters*

The contact strips of the pantographs shall comply with the basic parameters as given in section 4.1.

5.3.3.2. *Materials*

The material used for the pantograph contact strips shall be physically and electrically compatible with the contact wire material to avoid abrading the surface of the contact wires excessively, in order to keep wear of both wires and contact strips to a minimum. Plain carbon or carbon impregnated with additive material are accepted for use in interaction with contact wires made from copper or copper alloys. Therefore, this combination should preferably be used for the trans-European high-speed rail system.

Other material may be used in case of DC systems when multilaterally agreed upon. In this case the contact strips cannot be considered as interoperable. Reference is made to Annex M(M.2) to this TSI.

**▼B**5.3.3.3. *Current capacity*

The material and cross-section of contact strips shall be selected in the light of the maximum current the contact strip is designed for. The rated current shall be noted on it by the manufacturer. Type tests shall demonstrate the conformity as specified in Annex M(M.4) to this TSI.

5.3.3.4. *Current at standstill*

An acceptable level of current at standstill shall be acceptable for both the contact wire and pantograph collector strips to allow for the proper supply of auxiliaries installed on-board trains. For DC systems, in order to be in accordance with point 5.3.1.8, a current of 300 A shall be guaranteed per pantograph. A study shall be carried out to prove the capacity of the collector strips. For conformity assessment reference is made to Annex M(M.3) to this TSI.

5.3.3.5. *Detection of contact strip breakage*

The contact strip shall be designed so that any failures of the contact strips will be detected and the lowering of the pantograph will be triggered. Reference is made to EN 50 206-1, version 1998, point 4.9.

## 6. ASSESSMENT OF CONFORMITY AND/OR SUITABILITY FOR USE

### 6.1. Interoperability constituents

#### 6.1.1. *Assessment procedures and modules*

The assessment procedure for conformity of interoperability constituents as defined in Chapter 5 of this TSI shall be carried out by application of modules as specified in Annex A to this TSI.

If the adjudicating entity can demonstrate that tests or verification for previous applications remain valid for the new applications, then the notified body shall take them into account in the conformity assessment.

Assessment procedures for conformity of the interoperability constituents: overhead contact line, pantograph and contact strip as defined in Chapter 5 of this TSI, are indicated in Annex B, Tables B.1 to B.3 to this TSI.

As far as required by the modules specified in Annex A to this TSI, the assessment of conformity of an interoperability constituent shall be appraised by the notified body, when indicated in the procedure, with which the manufacturer or his authorised representative established within the Community has lodged the application.

The manufacturer of an interoperability constituent or his authorised representative established within the Community shall draw up an EC declaration of conformity in accordance with Article 13(1) of and Annex IV, Chapter 3 to Directive 96/48/EC before placing the interoperability constituent on the market. An EC declaration of suitability for use is not required for interoperability constituents of the energy subsystem.

**▼B****6.1.2. Application of modules**

For the assessment procedure of each interoperability constituent of the energy subsystem the manufacturer or his authorised representative established within the Community may choose either:

- the type-examination procedure (module B) indicated in Annex A(A.2) to this TSI for the design and development phase in combination with the conformity to type procedure (module C) indicated in Annex A(A.3) to this TSI for the production phase, or
- the full quality assurance with design examination procedure (module H2) indicated in Annex A(A.4) to this TSI for all phases.

These assessment procedures are defined in Annex A to this TSI.

The module H2 may only be chosen where the manufacturer operates a quality system for design, production, final product inspection and testing, approved and surveyed by a notified body.

The conformity assessment shall cover the phases and characteristics as indicated by X in the Tables B.1, B.2 and B.3 of Annex B to this TSI.

**6.2. Energy subsystem.****6.2.1. Assessment procedures and modules**

At the request of the adjudicating entity or its authorised representative established within the Community, the notified body carries out the EC verification in accordance with Article 18(1) of and Annex VI to Directive 96/48/EC and in accordance with the provisions of the relevant modules as specified in Annex A to this TSI.

If the adjudicating entity can demonstrate that tests or verification for previous applications remain valid for the new applications, then the notified body shall take them into account in the conformity assessment

Assessment procedures for the EC verification of the energy subsystem are indicated in Annex C, Table C.1, to this TSI.

As far as specified in this TSI the EC verification of the energy subsystem shall take account of its interfaces with other subsystems of the trans-European high-speed rail system.

The adjudicating entity shall draw up the EC declaration of verification for the Energy subsystem in accordance with Article 18(1) of and Annex V to Directive 96/48/EC.

**6.2.2. Application of modules**

For the verification procedure of the Energy subsystem the adjudicating entity or its authorised representative established within the Community may choose either:

- the unit verification procedure (module SG) indicated in Annex A(A.5) to this TSI, or
- the full quality assurance with design examination procedure (module SH2) indicated in Annex A(A.6) to this TSI.

**▼B**

The module SH2 may be chosen only where all activities contributing to the subsystem project to be verified (design, manufacturing, assembling, installation) are subject to a quality system for design, production, final product inspection and testing, approved and surveyed by a notified body.

The assessment shall cover the phases and characteristics as indicated in Table C.1 of Annex C to this TSI.

## **7. IMPLEMENTATION OF THE ENERGY TSI**

### **7.1. Application of this TSI to high-speed lines and rolling stock to put into service**

As to the high-speed lines within the geographic scope of this TSI (see section 1.2) and to the rolling stock which will be put into service after the entry into force of this TSI, Chapters 2 to 6 are entirely applicable, as well as possible specific provisions of section 7.3 hereafter.

### **7.2. Application of this TSI to high-speed lines and rolling stock already in service**

In respect of infrastructure installations and rolling stock already in operation, this TSI applies to components under the conditions specified in Article 3 of this Decision. In this particular context, it relates fundamentally to the application of a migration strategy that enables an economically justifiable adaptation of existing installations to be made taking into account the principle of grandfather rights. The following principles apply in the case of the TSI on energy.

While the TSI can be fully applied to new installations, implementation on existing lines may require modifications of existing installations. The modification necessary will depend on the extent of conformity of the existing installations. An implementation strategy can only be made individually for given lines or networks in the Member States of the Community. Section 7.3 indicates those items where implementation needs modification of existing installations. Table 7.1 summarises the characteristics to be implemented.

The contracting entity shall define the practical measures and the different phases which are necessary to allow placing into service with the required performances. These phases may include transition periods for placing into service with reduced performances.

*Table 7.1*

#### **Implementation of technical specifications for interoperability, energy subsystem**

Characteristic to be implemented	Point
Voltage and frequency	4.1.1
Installed power, mean useful voltage	4.3.1.1
Harmonic currents	4.2.2.3
Electrical protection	4.2.2.8
External electromagnetic compatibility	4.3.1.5
Protection against electric shock	4.3.1.8, 4.3.2.4
Isolation of power supply	4.3.1.10



**▼B**

Characteristic to be implemented	Point
Continuation of power supply	4.3.1.11
Regenerative braking	4.3.1.4
Geometry of overhead contact line	4.1.2.1, 4.1.2.2, 5.3.1.3
Dynamic envelope	4.2.2.4
Phase separation sections	4.2.2.10
System separation sections	4.2.2.11
Current capacity	5.3.1.2, 5.3.2.3, 5.3.3.3
Wave propagation speed	5.3.1.4
Elasticity and its uniformity	5.3.1.5
Mean contact force	5.3.1.6
Safety, earthing and bonding	4.3.1.2, 4.3.2.2
Dynamic behaviour and current collection	4.3.2.3
Design of pantographs	4.1.2.3
Design of collector strips	5.3.3
Contact forces	4.3.2.5

**7.3. Specific cases**

The following special provisions are authorised in the following specific cases. These specific cases are classified according to two categories: the provisions apply either permanently ('P' cases), or temporarily ('T' cases). As to temporarily cases, it is recommended that the target system is reached either by 2010 (cases 'T1'), an objective set in Decision No 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community guidelines for the development of the trans-European transport network, or by 2020 (cases 'T2').

**7.3.1. Particular features on the Austrian network****Connecting lines**

The investment of changing the overhead contact line on upgraded and connecting lines and in stations to meet the requirements of the 1 600 mm Euro pantograph is prohibitive. Trains traversing these lines will have to be provided with secondary 1 950 mm pantographs for medium-speed operation up to 230 km/h so that the overhead contact line on these parts of the trans-European network will not have to be prepared for the operation of the Euro pantograph. In these areas a maximum lateral deflection of contact wire of 550 mm under action of cross wind is permissible. Future studies concerning upgraded and connecting lines should take into account the Euro pantograph to demonstrate the relevance of the choices made.

**Connecting and upgraded lines (P case)**

Due to the acceptance of designing the overhead contact line for a 1 950 mm wide pantograph there is no need for adjustment.

**▼B**

## Connecting lines (T1 case)

To comply with the requirements on mean useful voltage and installed power additional substations are necessary. Installation is planned until 2010.

**7.3.2. Particular features on the Belgian network (T1 case)**

## Existing high-speed lines

On existing high-speed lines the phase separation sections are not compatible with the requirement of pantograph distance between three pantographs of more than 143 m. Between existing high-speed lines and upgraded lines there is no automatic control to trigger the opening of the main circuit breaker on the traction vehicles.

Both items have to be modified.

## Connecting and upgraded lines

On some line sections, under bridges, the contact wire height does not meet the TSI minimum requirements and will have to be modified. Dates are open.

**7.3.3. Particular features on the German network (P case)**

The investment of changing the overhead contact line on upgraded and connecting lines and in stations to meet the requirements of the 1 600 mm Euro pantograph is prohibitive. Trains traversing these lines will have to be provided with secondary 1 950 mm pantographs for medium-speed operation up to 230 km/h so that the overhead contact line on these parts of the trans-European network will not have to be prepared for the operation of the Euro pantograph. In these areas a maximum lateral deflection of contact wire of 550 mm under action of crosswind is permissible. Future studies concerning upgraded and connecting lines should take into account the Euro pantograph to demonstrate the relevance of the choices made.

**7.3.4. Particular features on the Spanish network (P case)**

The investment of changing the overhead contact line on upgraded and connecting lines and in stations to meet the requirements of the 1 600 mm Euro pantograph is prohibitive. Trains traversing these lines will have to be provided with secondary 1 950 mm pantographs for medium-speed operation up to 230 km/h so that the overhead contact line on these parts of the trans-European network will not have to be prepared for the operation of the Euro pantograph. In these areas a maximum lateral deflection of contact wire of 550 mm under action of crosswind is permissible. Future studies concerning upgraded and connecting lines should take into account the Euro pantograph to demonstrate the relevance of the choices made.

The nominal contact wire height can be 5,50 m on some sections of future high-speed lines in Spain; particularly in case of the future high-speed line between Barcelona and Perpignan. (It would concern also France between the Spanish border and Perpignan if this country asked for it.)

For the high-speed line Madrid-Seville, trains have to be equipped with a 1 950 mm pantograph.

**▼B****7.3.5. Particular features on the French network****Existing high-speed lines (T2 case)**

To provide for the criteria of current collection and dynamic behaviour on AC lines modification of overhead line equipment is necessary.

On existing high-speed lines the phase separation sections are not compatible with the pantograph arrangement between three pantographs of more than 143 m. Phase separation sections have to be modified.

On a specific high-speed line a modification of the overhead contact line is necessary to provide for the permissible uplift without uplift stops installed in the pantographs.

**Upgraded and connecting lines**

To provide for the criteria of current collection on DC lines modification of overhead line equipment is necessary. For DC lines the cross-section of contact wires is not sufficient to comply with the TSI requirements for current at standstill in stations or in areas where trains are pre-heated.

The existing DC line to Spain is operated with a 1 950 mm DC collector head. To operate this line with interoperable 1 600 mm Euro collector heads the overhead line has to be upgraded accordingly.

**All categories of lines**

The following applies for the pantographs:

- for AC systems a 1 600 mm Euro collector head is needed instead of 1 450 mm pan heads currently in use on TGVs,
- for DC systems a 1 600 mm Euro collector head is needed instead of 1 950 mm wide pan heads currently used on TGVs,
- for AC systems during an intermediate period, use of pantographs capable of operating with three targets curves (C1, C2 and target curve) for the mean contact force  $F_m$  is necessary,
- for DC systems the use of pantographs capable of operating with two  $F_m$  curves, one for 1,5 kV and another for 3 kV might be necessary.

The conversion has not yet been scheduled.

**7.3.6. Particular features on the British network****New high-speed lines (T1 case)**

On the planned Channel Tunnel railway line (CTRL) the phase separation sections may need adjusting to the specifications in the TSI. This amendment will be carried out with the introduction of full-service including freight trains.

**Upgraded lines (P case)**

On the east coast main line (ECML) some sections do not comply with the specifications for voltage and frequency, mean useful voltage and installed power. Implementation of the TSI is planned with the next major upgrade for the ECML.

**▼B**

On the ECML and the west coast main line (WCML) the geometry of overhead contact line and dynamic envelope are based on UK1 gauge and are treated as a special case. The variable contact wire height may be retained for speeds up to 225 km/h and the mean contact force will be adjusted to achieve the current collection requirements of EN 50 119, version 2001, point 5.2.1.

On the WCLM the existing type of phase separation sections will be retained.

7.3.7. **Particular features on the Italian network**

Existing high-speed lines (T1 case)

Geometry of overhead contact lines needs to be adjusted for height of contact wire on a length of 100 km double track line.

These modifications will be carried out until 2010.

Connecting and upgraded lines (T1 case)

Geometry of overhead contact lines needs to be adjusted concerning height of contact wire on parts of lines involved.

To comply with the requirements on mean useful voltage and installed power additional substations are necessary.

These modifications will be carried out until 2010.

7.3.8. **Particular features on the Irish and Northern Irish networks (P cases)**

On electrified lines of the Irish and Northern Irish networks, the IRL1 Irish standard structure gauge and the necessary clearances will define the nominal contact wire height.

7.3.9. **Particular features on the Swedish network (P case)**

The investment of changing the overhead contact line on upgraded and connecting lines and in stations to meet the requirements of the 1 600 mm Euro pantograph is prohibitive. Trains traversing these lines will have to be provided with secondary 1 950 mm pantographs for medium-speed operation up to 230 km/h so that the overhead contact line on these parts of the trans-European network will not have to be prepared for the operation of the Euro pantograph. In these areas a maximum lateral deflection of contact wire of 550 mm under action of crosswind is permissible. Future studies concerning upgraded and connecting lines should take into account the Euro pantograph to demonstrate the relevance of the choices made.

7.3.10. **Particular features on the Finnish network (P case)**

The normal height of the contact wire is 6 150 mm (minimum 5 600 mm, maximum 6 500 mm).



## ANNEX A

### ASSESSMENT PROCEDURES (MODULES)

- For conformity of interoperability constituents and
- For the EC verification of subsystems.

#### A.1. SCOPE

This annex covers the modules for the assessment procedures for the Conformity assessment of Interoperability Constituents and the EC verification of the Energy subsystem.

#### A.2. MODULE B (TYPE-EXAMINATION)

##### Conformity assessment of interoperability constituents

1. This module describes that part of the procedure by which a notified body ascertains and attests that a type, representative of the production envisaged, meets the provisions of the TSI that apply to it.
2. The application for the type-examination must be lodged by the manufacturer or his authorised representative established within the Community with a notified body of his choice.

The application must include:

- the name and address of the manufacturer and, if the application is lodged by the authorised representative, his name and address in addition,
- a written declaration that the same application has not been lodged with any other notified body,
- the technical documentation, as described in point 3.

The applicant must place at the disposal of the notified body a specimen, representative of the production envisaged, and hereinafter called 'type'.

A type may cover several versions of the interoperability constituent provided that the differences between the versions do not affect the provisions of the TSI.

The notified body may request further specimens if needed for carrying out the test programme.

If no type tests are requested within the type-examination procedure (see point 4.4), and the type is sufficiently defined by the technical documentation, as described in point 3, the notified body may agree, that no specimens are placed at their disposal.

3. The technical documentation must enable the conformity of the interoperability constituent with the provisions of the TSI to be assessed. It must, as far as relevant for such assessment, cover the design, manufacture and operation of the product.

The technical documentation must contain:

- a general type-description,
- conceptual design and manufacturing drawings and schemes of components, sub-assemblies, circuits, etc.,
- descriptions and explanations necessary for the understanding of said drawings and schemes and the operation of the product,

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- conditions of integration of the interoperability constituent in its system environment (sub-assembly, assembly, subsystem) and the necessary interface conditions,
  - conditions for use and maintenance of the interoperability constituent (restrictions of running time or distance, wear limits etc),
  - a list of the technical specifications, against which the conformity of the interoperability constituent is to be assessed (relevant TSI and/or European specification with relevant clauses),
  - descriptions of the solutions adopted to meet the requirements of the TSI in cases where the European specification referred to in the TSI have not been applied in full,
  - results of design calculations made, examinations carried out, etc.,
  - test reports.
4. The notified body must:
- 4.1. examine the technical documentation,
  - 4.2. if a design review is requested in the TSI, perform an examination of the design methods, the design tools and the design results to evaluate their capability to fulfil the requirements for conformity for the interoperability constituent at the completion of the design process,
  - 4.3. if a review of the manufacturing process is requested in the TSI, perform an examination of the manufacturing process devised for manufacturing the interoperability constituent, to evaluate its contribution to product conformity, and/or examine the review carried out by the manufacturer at the completion of the design process,
  - 4.4. if type tests are requested in the TSI, verify that the specimen(s) has (have) been manufactured in conformity with the technical documentation, and carry out or have carried out the type tests in accordance with the provisions of the TSI and the European specification referred to in the TSI,
  - 4.5. identify the elements which have been designed in accordance with the relevant provisions of the TSI and the European specification referred to in the TSI, as well as the elements which have been designed without applying the relevant provisions of those European specifications,
  - 4.6. perform or have performed the appropriate examinations and necessary tests in accordance with point 4.2, 4.3 and 4.4 to establish whether, where the appropriate European specification referred to in the TSI have not been applied, the solutions adopted by the manufacturer meet the requirements of the TSI,
  - 4.7. perform or have performed the appropriate examinations and necessary tests in accordance with point 4.2, 4.3 and 4.4 to establish whether, where the manufacturer has chosen to apply the relevant European specification, these have actually been applied,
  - 4.8. agree with the applicant the location where the examinations and necessary tests will be carried out.
5. Where the type meets the provisions of the TSI, the notified body must issue a type-examination certificate to the applicant. The certificate must contain the name and address of the manufacturer, conclusions of the examination, conditions for its validity and the necessary data for identification of the approved type.

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The time period of validity shall be no longer than three years.

A list of the relevant parts of the technical documentation must be annexed to the certificate and a copy kept by the notified body.

If the manufacturer or his authorised representative established within the Community is denied an EC type-examination certificate, the notified body must provide detailed reasons for such denial.

Provision must be made for an appeals procedure.

6. The applicant must inform the notified body that holds the technical documentation concerning the EC type-examination certificate of all modifications to the approved product which must receive additional approval where such changes may affect the conformity with the requirements of the TSI or the prescribed conditions for use of the product. This additional approval is given in the form of an addition to the original type-examination certificate, or a new certificate will be issued after withdrawal of the old certificate.
7. If no modifications as under point 6 have been made, the validity of an expiring certificate can be extended for another period of validity. The applicant will apply for such a prolongation by a written confirmation that no such modifications have been made, and the notified body issues a prolongation for another period of validity as in point 5, if no contrary information exists. This procedure can be reiterated.
8. Each notified body must communicate to the other notified bodies the relevant information concerning the type-examination certificates it has withdrawn or refused.
9. The other notified bodies will receive copies of the type-examination certificates issued and/or their additions on request. The annexes to the certificates must be kept at the disposal of the other notified bodies.
10. The manufacturer or his authorised representative established within the Community must keep with the technical documentation copies of the EC type-examination certificates and their additions for a period of 10 years after the last product has been manufactured. Where neither the manufacturer nor his authorised representative is established within the Community, the obligation to keep the technical documentation available is the responsibility of the person who places the product on the Community market.

### A.3. MODULE C (CONFORMITY TO TYPE)

#### **Conformity assessment of interoperability constituents**

1. This module describes that part of the procedure whereby the manufacturer or his authorised representative established within the Community ensures and declares that the interoperability constituent concerned is in conformity with the type as described in the EC type-examination certificate and satisfies the requirements of Directive 96/48/EC and of the TSI that apply to it.
2. The manufacturer must take all measures necessary to ensure that the manufacturing process ensures compliance of the manufactured interoperability constituents with the type as described in the EC type-examination certificate and with the requirements of Directive 96/48/EC and of the TSI that apply to them.
3. The manufacturer or his authorised representative established within the Community must draw up an EC declaration of conformity of the interoperability constituent.

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The content of this declaration has to include at least the information, indicated in Directive 96/48/EC, Annex IV (3) and Article 13(3). The EC declaration of conformity and the accompanying documents must be dated and signed.

The declaration must be written in the same language of the technical file and must contain the following:

- the Directive reference (Directive 96/48/EC and other directives to which the interoperability constituent may be subject),
- the name and address of the manufacturer or his authorised representative established within the Community (give trade name and full address and in the case of authorised representative also give the trade name of the manufacturer or constructor),
- description of interoperability constituent (make, type etc.)
- description of the procedure (module) followed in order to declare conformity,
- all the relevant descriptions met by the interoperability constituent and in particular its conditions of use,
- name and address of the notified body(ies) involved in the procedure followed in respect of conformity and date of examination certificates together with the duration and conditions of validity of the certificate,
- reference to this TSI and to any other applicable TSI, and where appropriate reference to European specification,
- identification of signatory having received power to engage the manufacturer or his authorised representative established within the Community.

The certificates to be referred to are:

- the type-examination certificate and its additions.
4. The manufacturer or his authorised representative established within the Community must keep a copy of the EC declaration of conformity for a period of 10 years after the last interoperability constituent has been manufactured.

Where neither the manufacturer nor his authorised representative is established within the Community, the obligation to keep the technical documentation available is the responsibility of the person who places the interoperability constituent on the Community market.

5. If additional to the EC declaration of conformity an EC declaration of suitability for use for the interoperability constituent is requested in the TSI, this declaration has to be added, after being issued by the manufacturer under the conditions of module V.

#### A.4. MODULE H2 (FULL QUALITY ASSURANCE WITH DESIGN EXAMINATION)

##### **Conformity assessment of interoperability constituents**

1. This module describes the procedure whereby a notified body carries out an examination of the design of an interoperability constituent and the manufacturer or his authorised representative established within the Community who satisfies the obligations of point 2 ensures and declares that the interoperability constituent concerned satisfies the requirements of Directive 96/48/EC and of the TSI that apply to it.



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2. The manufacturer must operate an approved quality system for design, manufacture and final product inspection and testing as specified in point 3 and shall be subject to surveillance as specified in point 4.

3. Quality system

- 3.1. The manufacturer must lodge an application for assessment of his quality system with a notified body.

The application must include:

- all relevant information for the product category representative for the interoperability constituent envisaged,
- the quality system's documentation.

- 3.2. The quality system must ensure compliance of the interoperability constituent with the requirements of Directive 96/48/EC and of the TSI that apply to it. All the elements, requirements and provisions adopted by the manufacturer must be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. This quality system documentation shall ensure a common understanding of the quality policies and procedures such as quality programmes, plans, manuals and records.

It must contain in particular an adequate description of:

- the quality objectives and the organisational structure,
- responsibilities and powers of the management with regard to design and product quality,
- the technical design specifications, including European specifications, that will be applied, and, where the European specifications referred to in Article 10 of Directive 96/48/EC will not be applied in full, the means that will be used to ensure that the requirements of the Directive and of the TSI that apply to the interoperability constituent will be met,
- the design control and design verification techniques, processes and systematic actions that will be used when designing the interoperability constituents pertaining to the product category covered,
- the corresponding manufacturing, quality control and quality assurance techniques, processes and systematic actions that will be used,
- the examinations and tests that will be carried out before, during and after manufacture, and the frequency with which they will be carried out,
- the quality records, such as inspection reports and test data, calibration data, qualification reports of the personnel concerned, etc.,
- the means to monitor the achievement of the required design and product quality and the effective operation of the quality system.

The quality policies and procedures shall cover in particular the assessment phases, as design review, review of manufacturing process and type tests, as they are specified in the TSI for different characteristics and performances of the interoperability constituent.

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- 3.3. The notified body must assess the quality system to determine whether it satisfies the requirements referred to in point 3.2. It shall presume compliance with these requirements in respect of quality systems that implement the relevant harmonised standard. This harmonised standard shall be EN ISO 9001 - December 2000, completed if necessary to take into consideration the specificity of the interoperability constituent for which it is implemented.

The audit must be specific for the product category, which is representative for the interoperability constituent. The auditing team must have at least one member experienced as an assessor in the product technology concerned. The evaluation procedure shall include an assessment visit to the manufacturer's premises.

The decision must be notified to the manufacturer. The notification must contain the conclusions of the examination and the reasoned assessment decision.

- 3.4. The manufacturer must undertake to fulfil the obligations arising out of the quality system as approved and to uphold it so that it remains adequate and efficient.

The manufacturer or his authorised representative must keep the notified body that has approved the quality system informed of any intended updating of the quality system.

The notified body must evaluate the modifications proposed and decide whether the amended quality system will still satisfy the requirements referred to in point 3.2 or whether a re-assessment is required.

It must notify its decision to the manufacturer. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

4. Surveillance of the quality system under the responsibility of the notified body

- 4.1. The purpose of surveillance is to make sure that the manufacturer duly fulfils the obligations arising out of the approved quality system.

- 4.2. The manufacturer must allow the notified body entrance for inspection purposes to the locations of design, manufacture, inspection and testing, and storage, and shall provide it with all necessary information, in particular:

- the quality system documentation,
- the quality records as foreseen by the design part of the quality system, such as results of analyses, calculations, tests, etc.,
- the quality records as foreseen by the manufacturing part of the quality system, such as inspection reports and test data, calibration data, qualification reports of the personnel concerned, etc.

- 4.3. The notified body must periodically carry out audits to make sure that the manufacturer maintains and applies the quality system and shall provide an audit report to the manufacturer.

The frequency of the audits shall be at least once a year.

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- 4.4. Additionally the notified body may pay unexpected visits to the manufacturer. At the time of such visits, the notified body may carry out tests or have them carried out in order to check the proper functioning of the quality system where necessary; it must provide the manufacturer with a visit report and, if a test has been carried out, with a test report.
5. The manufacturer must, for a period of 10 years after the last product has been manufactured, keep at the disposal of the national authorities:
  - the documentation referred to in the second indent of the second subparagraph of point 3.1,
  - the updating referred to in the second subparagraph of point 3.4,
  - the decisions and reports from the notified body which are referred to in the final subparagraph of point 3.4, points 4.3 and 4.4.
6. Design examination
  - 6.1. The manufacturer must lodge an application for examination of the design of the interoperability constituent with a notified body.
  - 6.2. The application must enable the design, manufacture and operation of the interoperability constituent to be understood, and shall enable conformity with the requirements of Directive 96/48/EC and of the TSI to be assessed.

It must include:

- the technical design specifications, including European specifications, that have been applied,
  - the necessary supporting evidence for their adequacy, in particular where the European specifications referred to in Article 10 of the Directive have not been applied in full. This supporting evidence must include the results of tests carried out by the appropriate laboratory of the manufacturer or on his behalf.
- 6.3. The notified body must examine the application and where the design meets the provisions of the TSI that apply to it must issue a design examination certificate to the applicant. The certificate shall contain the conclusions of the examination, conditions for its validity, the necessary data for identification of the approved design and, if relevant, a description of the product's functioning.

The time period of validity shall be no longer than three years.

- 6.4. The applicant must keep the notified body that has issued the design examination certificate informed of any modification to the approved design. Modifications to the approved design must receive additional approval from the notified body that issued the design examination certificate where such changes may affect the conformity with the requirements of the TSI or the prescribed conditions for use of the product. This additional approval is given in the form of an addition to the original design examination certificate.
- 6.5. If no modifications as under point 6.4. have been made, the validity of an expiring certificate can be extended for another period of validity. The applicant will apply for such a prolongation by a written confirmation that no such modifications have been made, and the notified body issues a prolongation for another period of validity as in point 6.3 if no contrary information exists. This procedure can be reiterated.

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7. Each notified body must communicate to the other notified bodies the relevant information concerning the quality system approvals and the design examination certificates that it has withdrawn or refused.

The other notified bodies will receive copies of:

- the quality system approvals and additional approvals issued and
- the design examination certificates and additions issued

on request.

8. The manufacturer or his authorised representative established within the Community must draw up the EC declaration of conformity of the interoperability constituent.

The content of this declaration has to include at least the information, indicated in Directive 96/48/EC, Annex IV(3) and Article 13(3). The EC declaration of conformity and its accompanying documents must be dated and signed.

The declaration must be written in the same language of the technical file and must contain the following:

- the Directive references (Directive 96/48/EC and other directives to which the interoperability constituent may be subject),
- the name and address of the manufacturer or his authorised representative established within the Community (give trade name and full address and in the case of authorised representative also give the trade name of the manufacturer or constructor),
- description of interoperability constituent (make, type, etc)
- description of the procedure (module) followed in order to declare conformity,
- all of the relevant descriptions met by the interoperability constituent and in particular its conditions of use,
- name and address of notified body(ies) involved in the procedure followed in respect of conformity and date of examination certificates together with the duration and conditions of validity of the certificate,
- reference to this TSI and other applicable TSIs and where appropriate to European specifications,
- identification of signatory having received power to engage the manufacturer or his authorised representative established within the Community.

The certificates to be referred to are:

- the quality system approval and surveillance reports indicated in points 3 and 4,
- the design examination certificate and its additions.

9. The manufacturer or his authorised representative established within the Community must keep a copy of the EC declaration of conformity for a period of 10 years after the last interoperability constituent has been manufactured.

Where neither the manufacturer nor his authorised representative is established within the Community, the obligation to keep the technical documentation available is the responsibility of the person who places the interoperability constituent on the Community market.

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10. If additional to the EC declaration of conformity an EC declaration of suitability for use for the interoperability constituent is requested in the TSI, this declaration has to be added, after being issued by the manufacturer under the conditions of module V.

**A.5. MODULE SG (UNIT VERIFICATION)****EC verification of the energy subsystem**

1. This module describes the EC verification procedure whereby a notified body checks and certifies, at the request of an adjudicating entity or its authorised representative established within the Community, that an energy subsystem:
  - complies with this TSI and any other applicable TSI, which demonstrates that the essential requirements of Directive 96/48/EC have been met,
  - complies with the other regulations deriving from the Treaty and may be put into service.
2. The adjudicating entity or its authorised representative established within the Community must lodge an application for EC verification (through unit verification) of the subsystem with a notified body of his choice.

The application includes:

- name and address of the adjudicating entity or its authorised representative,
  - the technical documentation.
3. The technical documentation must enable the design, manufacture, installation and operation of the subsystem to be understood, and shall enable conformity with the requirements of the TSI to be assessed.

It must include:

- a general description of the subsystem, overall design and structure,
- the register of infrastructure, including all indications as specified in the TSI,
- conceptual design and manufacturing drawings and schemes of subassemblies, circuits, etc.,
- technical documentation as regards the manufacturing and the assembling of the subsystem,
- the technical design specifications, including European specifications, that have been applied,
- the necessary supporting evidence for their adequacy, in particular where European specifications referred to in the TSI and the relevant clauses have not been applied in full,
- a list of the interoperability constituents, to be incorporated into the subsystem,
- a list of manufacturers, involved in the subsystem's design, manufacturing, assembling and installation,
- a list of the European specifications referred to in the TSI or in the technical design specification.

If the TSI is requiring further information for the technical documentation, this has to be included.

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4. The notified body must examine the application, and carry out the appropriate tests and verifications as set out in the TSI and/or in the European specifications referred to in the TSI, to ensure conformity with the essential requirements of the Directive as provided for in the TSI. The examinations, tests and checking shall extend to the following stages as provided for in the TSI:
  - overall design
  - structure of subsystem, including, in particular and when relevant, civil-engineering activities, constituent assembly and, overall adjustments,
  - final testing of the subsystem,
  - and, whenever specified in the TSI, the validation under full operational conditions.
5. The notified body may agree with the adjudicating entity the locations where the tests will be carried out and may agree that final subsystem tests and, whenever required in the TSI, tests in full operating conditions, are carried out by the adjudicating entity under direct supervision and attendance of the notified body.
6. The notified body must have permanent access for testing and verification purposes to the locations of design, building sites, production workshops, locations of assembling and installations, and where appropriate, prefabrication and testing facilities in order to carry out its tasks as provided for in the TSI.
7. Where the subsystem meets the requirements of the TSI, the notified body must then, based on the tests, verifications and checking carried out as required in the TSI and in the European specifications referred to in the TSI, draw up the certificate of EC verification intended for the adjudicating entity or its authorised representative established within the Community, which in turn draws up the EC declaration of verification intended for the supervisory authority in the Member State where the subsystem is located and/or operates. The EC declaration of verification and the accompanying documents must be dated and signed. The declaration must be written in the same language of the technical file and must contain at least the information included in Annex V to Directive 96/48/EC.
8. The notified body shall be responsible for compiling the technical file that has to accompany the EC declaration of verification. The technical file has to include at least the information indicated in Directive 96/48/EC, Article 18(3), and in particular as follows:
  - all necessary documents relating to the characteristics of the subsystem,
  - list of interoperability constituents incorporated into the subsystem,
  - copies of the EC declarations of conformity and, where appropriate, of the EC declarations of suitability for use, which said constituents must be provided in accordance with Article 13 of the Directive, accompanied, where appropriate, by the corresponding documents (certificates, quality system approval and surveillance documents) issued by the notified bodies on the basis of the TSI,
  - all elements relating to conditions and limits for use,
  - all elements relating to the instructions concerning servicing, constant or routine monitoring, adjustment and maintenance,

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- certificate of EC verification of the notified body as mentioned under point 7, accompanied by corresponding calculation notes and countersigned by itself, stating that the project complies with the Directive and the TSI, and mentioning, where appropriate, reservations recorded during performance of activities and not withdrawn; the certificate should also be accompanied, if relevant, by the inspection and audit reports drawn up in connection with the verification,
  - the register of infrastructure, including all indications as specified in the TSI.
9. The complete records accompanying the certificate of EC verification must be lodged with the adjudicating entity or its authorised representative in support of the certificate of EC verification issued by the notified body and must be attached to the EC declaration of verification drawn up by the adjudicating entity intended for the supervisory authority.
  10. The adjudicating entity or its authorised representative within the Community must keep a copy of the records throughout the service life of the subsystem; it must be sent to any other Member State who so requests.

#### A.6. MODULE SH2 (FULL QUALITY ASSURANCE WITH DESIGN EXAMINATION)

##### **EC verification of the energy subsystem**

1. This module describes the EC verification procedure whereby a notified body checks and certifies, at the request of an adjudicating entity or its authorised representative established within the Community, that an energy subsystem:
  - complies with this TSI and any other applicable TSI, which demonstrates that the essential requirements of Directive 96/48/EC have been met,
  - complies with the other regulations deriving from the Treaty and may be put into service.

The notified body carries out the procedure, including a design examination of the subsystem under the condition that the adjudicating entity and the manufacturers involved satisfy the obligations of point 2.
2. For the subsystem, being subject of the EC verification procedure, the adjudicating entity must contract only with manufacturers, whose activities contributing to the subsystem project to be verified (design, manufacturing, assembling, installation) are subject to an approved quality system for design, manufacture and final product inspection and testing as specified in point 3 and which shall be subject to surveillance as specified in point 4.

The term ‘manufacturer’ also includes companies:

- responsible for the whole subsystem project (including in particular responsibility for subsystem integration (main contractor),
- performing design services or studies (e.g. consultants),
- performing assembling (assemblers) and installation of the subsystem. For manufacturers, performing only assembling and installation, a quality system for manufacture and final product inspection and testing is sufficient.

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The main contractor responsible for the whole subsystem project (including in particular responsibility for subsystem integration), must operate in any case an approved quality system for design, manufacture and final product inspection and testing, as specified in point 3 and which shall be subject to surveillance as specified in point 4.

In the case, that the adjudicating entity is directly involved in the design and/or production (including assembling and installation), or that the adjudicating entity itself is responsible for the whole subsystem project (including in particular responsibility for subsystem integration), it has to operate an approved quality system for those activities, as specified in point 3 and subject to surveillance as specified in point 4.

### 3. Quality system

- 3.1. The manufacturer(s) involved and, if involved, the adjudicating entity must lodge an application for assessment of their quality system with a notified body of their choice.

The application must include:

- all relevant information for the subsystem envisaged,
- the quality system's documentation.

For manufacturers, only involved in a part of the subsystem project, the information is only requested for that specific relevant part.

- 3.2. For the main contractor the quality system must ensure overall compliance of the subsystem with the requirements of Directive 96/48/EC and of the TSI. For other manufacturers (sub-suppliers) the quality system has to ensure compliance of their relevant contribution to the subsystem with the requirements of the TSI.

All the elements, requirements and provisions adopted by the applicants must be documented in a systematic and orderly manner in the form of written policies, procedures and instructions. This quality system documentation shall ensure a common understanding of the quality policies and procedures such as quality programmes, plans, manuals and records.

It must contain in particular an adequate description of the following items:

- for all applicants:
  - the quality objectives and the organisational structure,
  - the corresponding manufacturing, quality control and quality assurance techniques, processes and systematic actions that will be used,
  - the examinations, the checking and tests that will be carried out before, during and after manufacture, assembling and installation and the frequency with which they will be carried out,
  - the quality records, such as inspection reports and test data, calibration data, qualification reports of the personnel concerned, etc.,



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- for the main contractor and for the sub-suppliers (only as far as relevant for their specific contribution to the subsystem project):
  - the technical design specifications, including European specifications, that will be applied and, where the European specifications referred to in Article 10 of the Directive will not be applied in full, the means that will be used to ensure that the requirements of the TSI that apply to the subsystem will be met,
  - the design control and design verification techniques, processes and systematic actions that will be used when designing the subsystem,
  - the means to monitor the achievement of the required design and subsystem quality and the effective operation of the quality system,
- and for the main contractor:
  - responsibilities and powers of the management with regard to overall design and subsystem quality, including in particular the subsystem integration management.

The examinations, tests and checking shall cover all of the following stages:

- overall design,
  - structure of subsystem, including, in particular, civil-engineering activities, constituent assembly, final adjustment,
  - final testing of the subsystem,
  - and, where specified in the TSI, the validation under full operation conditions.
- 3.3. The notified body referred to in point 3.1 must assess the quality system to determine whether it satisfies the requirements referred to in point 3.2. It shall presume compliance with these requirements in respect of quality systems that implement the relevant harmonised standard. This harmonised standard shall be EN ISO 9001 - December 2000, completed if necessary to take into consideration the specificity of the subsystem for which it is implemented.

For applicants, who are only involved in assembling and installation, the harmonised standard shall be EN ISO 9001 - December 2000, completed if necessary to take into consideration the specificity of the subsystem for which it is implemented.

The audit shall be specific for the subsystem concerned, taking into consideration the specific contribution of the applicant to the subsystem. The auditing team must have at least one member experienced as an assessor in the subsystem technology concerned. The evaluation procedure shall include an assessment visit to the applicant's premises.

The decision must be notified to applicant. The notification must contain the conclusions of the examination and the reasoned assessment decision.

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- 3.4. The manufacturer(s) and, if involved the adjudicating entity must undertake to fulfil the obligations arising out of the quality system as approved and to uphold it so that it remains adequate and efficient.

They must keep the notified body that has approved their quality system informed of any intended updating of the quality system.

The notified body must evaluate the modifications proposed and decide whether the amended quality system will still satisfy the requirements referred to in point 3.2 or whether a re-assessment is required.

It must notify its decision to the applicant. The notification shall contain the conclusions of the examination and the reasoned assessment decision.

4. Surveillance of the quality system(s) under the responsibility of the notified body(ies)

- 4.1. The purpose of surveillance is to make sure that the manufacturer(s) and if involved the adjudicating entity duly fulfil the obligations arising out of the approved quality system.

- 4.2. The notified body(ies) as referred to under point 3.1. must have permanent access for inspection purposes to the locations of design, building sites, production workshops, locations of assembling and installation, storage areas and, where appropriate, prefabrication or testing facilities and, more general, to all premises which it considers necessary for its task, in accordance with the applicant's specific contribution to the subsystem project.

- 4.3. The manufacturer(s) and, if involved the adjudicating entity or its authorised representative established within the Community must send the notified body referred to under point 3.1 (or have sent it) all the documents needed for that purpose and in particular the implementation plans and technical records concerning the subsystem (as far as relevant for the specific contribution of the applicant to the subsystem), in particular:

— the quality system documentation, including the particular means implemented to ensure that:

— (for the main contractor) overall responsibilities and powers of the management for the compliance of the whole entire subsystem are sufficiently and properly defined,

— the quality systems of each manufacturer are correctly managed for achieving integration at subsystem level,

— the quality records as foreseen by the design part of the quality system, such as results of analyses, calculations, tests, etc.,

— the quality records as foreseen by the manufacturing part (including assembling and installation) of the quality system, such as inspection reports and test data, calibration data, qualification reports of the personnel concerned, etc.

- 4.4. The notified body(ies) must periodically carry out audits to make sure that the manufacturer(s) and, if involved the adjudicating entity maintain and apply the quality system and shall provide an audit report to them.

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The frequency of the audits shall be at least once a year, with at least one audit during the time period of performing relevant activities (design, manufacture, assembling or installation) for the subsystem being the subject of the EC verification procedure mentioned under point 6.

- 4.5. Additionally the notified body(ies) may pay unexpected visits to the sites mentioned under point 4.2 of the applicant(s). At the time of such visits, the notified body may conduct complete or partial audits in order to check the proper functioning of the quality system where necessary; it must provide the applicant(s) with an inspection report and, if an audit has been carried out, with an audit report.
5. The manufacturer(s) and, if involved the adjudicating entity must, for a period of 10 years after the last subsystem has been manufactured, keep at the disposal of the national authorities:
  - the documentation referred to in the second indent of the second subparagraph of point 3.1,
  - the updating referred to in the second subparagraph of point 3.4,
  - the decisions and reports from the notified body which are referred to in the final subparagraph of point 3.4, points 4.4 and 4.5.
6. EC verification procedure
  - 6.1. The adjudicating entity or its authorised representative established within the Community must lodge an application for EC verification of the subsystem (through full quality assurance with design examination), including coordination of surveillance of the quality systems as under points 4.4. and 4.5., with a notified body of its choice. The adjudicating entity or its authorised representative established within the Community must inform the manufacturers involved of his choice and of the application.
  - 6.2. The application must enable the design, manufacture, installation and operation of the subsystem to be understood, and shall enable conformity with the requirements of the TSI to be assessed.

It must include:

- the technical design specifications, including European specifications, that have been applied,
- the necessary supporting evidence for their adequacy, in particular where the European specifications referred to in the TSI have not been applied in full. This supporting evidence must include the results of tests carried out by the appropriate laboratory of the manufacturer or on his behalf,
- the energy subsystem register, including all indications as specified in the TSI,
- the technical documentation as regards the manufacturing and the assembling of the subsystem,
- a list of the interoperability constituents, to be incorporated into the subsystem,
- a list of all manufacturers, involved in the subsystem's design, manufacturing, assembling and installation,

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- the demonstration, that all stages, as mentioned under point 3.2, are covered by quality systems of the manufacturer(s) and/or of the adjudicating entity involved, and the evidence of their effectiveness,
- indication of the notified body(ies), responsible for the approval and surveillance of these quality systems.

- 6.3. The notified body must examine the application concerning the design examination and where the design meets the provisions of Directive 96/48/EC and of the TSI that apply to it must issue a design examination report to the applicant. The report shall contain the conclusions of the design examination, conditions for its validity, the necessary data for identification of the design examined and, if relevant, a description of the subsystem's functioning.
- 6.4. The notified body must, concerning the other stages of the EC verification examine, if all stages of the subsystem as mentioned under point 3.2 are sufficiently and properly covered by the approval and surveillance of quality system(s).

If the compliance of the subsystem with the requirements of the TSI is based on more than one quality system, it has to examine in particular:

- if the relations and interfaces between the quality systems are clearly documented,
  - and if overall responsibilities and powers of the management for the compliance of the whole entire subsystem for the main contractor are sufficiently and properly defined.
- 6.5. The notified body responsible for the EC verification, if not carrying out the surveillance of the quality system(s) concerned as under point 4, must coordinate the surveillance activities of any other notified body responsible for that task, in order to be ensured that correct management of interfaces between the different quality systems in view of subsystem integration has been performed. This coordination includes the right of the notified body responsible for the EC verification:
- to receive all documentation (approval and surveillance), issued by the other notified body(ies),
  - to witness the surveillance audits as under point 4.4,
  - to initiate additional audits as under point 4.5 under its responsibility and together with the other notified body(ies).
- 6.6. Where the subsystem meets the requirements of Directive 96/48/EC and of the TSI, the notified body must then — based on the design examination and the approval and surveillance of the quality system(s) — draw up the certificate of EC verification intended for the adjudicating entity or its authorised representative established within the Community, which in turn draws up the EC declaration of verification intended for the supervisory authority in the Member State within which the subsystem is located and/or operates.

The EC declaration of verification and the accompanying documents must be dated and signed. The declaration must be written in the same language of the technical file and must contain at least the information included in Annex V to Directive 96/48/EC.

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- 6.7. The notified body shall be responsible for compiling the technical file that has to accompany the EC declaration of verification. The technical file has to include at least the information indicated in Directive 96/48/EC, Article 18(3), and in particular as follows:
- all necessary documents relating to the characteristics of the subsystem,
  - list of interoperability constituents incorporated into the subsystem,
  - copies of the EC declarations of conformity and, where appropriate, of the EC declarations of suitability for use, which said constituents must be provided in accordance with Article 13 of the Directive, accompanied, where appropriate, by the corresponding documents (certificates, quality system approval and surveillance documents) issued by the notified bodies on the basis of the TSI,
  - all elements relating to the conditions and limits for use,
  - all elements relating to the instructions concerning servicing, constant or routine monitoring, adjustment and maintenance,
  - certificate of EC verification of the notified body as mentioned under point 6.6, accompanied by corresponding calculation notes and countersigned by itself, stating that the project complies with the Directive and the TSI, and mentioning, where appropriate, reservations recorded during performance of the activities and not withdrawn;
- the certificate should also be accompanied by the inspection and audit reports drawn up in connection with the verification, as mentioned under points 4.4, and 4.5,
- the energy subsystem register, including all indications as specified in the TSI.
7. The complete records accompanying the certificate of EC verification must be lodged with the adjudicating entity or its authorised representative in support of the certificate of EC verification issued by the notified body and must be attached to the EC declaration of verification drawn up by the adjudicating entity intended for the supervisory authority.
8. The adjudicating entity or its authorised representative within the Community must keep a copy of the records throughout the service life of the subsystem; it must be sent to any other Member State who so requests.



## ANNEX B

## ASSESSMENT OF INTEROPERABILITY CONSTITUENTS

## B.1. SCOPE

This Annex indicates the assessment of conformity of interoperability constituents (overhead contact line, pantograph and contact strip) of the energy subsystem.

## B.2. CHARACTERISTICS

The characteristics of the interoperability constituents to be assessed in the different phases of design and production are marked by an X in Tables B.1 to B 3.

Table B.1

## Assessment of the interoperability constituent: overhead contact line

1		2	3	4	5	6
Characteristics to be assessed		Assessment in the following phase				
		Design and development phase				Production phase (Series)
		Design review	Review of manufacturing process	Type test	In-service experience	
Geometry AC	4.1.2.1	X	n. a.	X	n. a.	X
Geometry DC	4.1.2.2					
Overall design	5.3.1.1					
Basic parameters	5.3.1.3					
Current capacity	5.3.1.2	X	n. a.	n. a.	n. a.	n. a.
Wave propagation speed	5.3.1.4	X	n. a.	n. a.	n. a.	n. a.
Elasticity and uniformity of elasticity	5.3.1.5	X	n. a.	X	n. a.	n. a.
Mean contact force	5.3.1.6	X	n. a.	X	n. a.	n. a.
Current at stand-still	5.3.1.8	X	n. a.	X	n. a.	n. a.
Maintenance	5.3.1.7	n. a.	n. a.	n. a.	n. a.	X

n. a.: not applicable.



Table B.2

**Assessment the interoperability constituents: pantograph**

1		2	3	4	5	6
Characteristics to be assessed		Assessment in the following phase				
Characteristic	Point	Design and development phase				Production phase (Series)
		Design review	Review of manufacturing process	Type test	In-service experience	
Overall design	5.3.2.1	X	n. a.	X	n. a.	X
Geometry of collector head	4.1.2.3, 5.3.2.2	X	n. a.	n. a.	n. a.	X
Current capacity	5.3.2.3	X	n. a.	n. a.	n. a.	X
Design of insulation	5.3.2.4	X	n. a.	X	n. a.	X
Working range	5.3.2.5	X	n. a.	n. a.	n. a.	X
Static contact force	4.3.2.5, 5.3.2.6	X	n. a.	X	n. a.	X
Mean contact force and interaction performance	5.3.2.7	X	n. a.	X	n. a.	X
Alternative contact force stipulations:	5.3.2.7	X	n. a.	X	n. a.	X
Automatic dropping devices	5.3.2.8	X	n. a.	X	n. a.	X
Current at stand-still	5.3.2.9	X	n. a.	X	n. a.	n. a.

N.B.: with 25 kV/95 kV 50 Hz 1 min and 250 kV peak, 1,2/50 µs.  
n. a.: not applicable.

n. a.: not applicable.





## ANNEX C

## ASSESSMENT OF THE ENERGY SUBSYSTEM

## C.1. SCOPE

This Annex indicates the assessment of conformity of the energy subsystem.

## C.2. CHARACTERISTICS AND MODULES

The characteristics of the subsystem to be assessed in the different phases of design, installation and operation are marked by an X in Table C.1.

Table C.1

## Assessment of the energy subsystem

1		2	3	4	5
Characteristics to be assessed		Assessment in the following phase			
		Design and development phase	Production phase		
		Design review	Construction, assembling, mounting	Assembled, before putting into service	Validation under full operating conditions
Geometry of overhead contact line	4.1.2.1,	X	X	X	n. a.
	4.1.2.2				
Safety, earthing and bonding	4.3.1.2,	X	X	n. a.	n. a.
	4.3.2.2				
Gradient of contact wire	4.1.2.1,	X	n. a.	X	n. a.
	4.1.2.2				
Dynamic envelope	4.2.2.4	X	n. a.	n. a.	n. a.
Phase separation sections	4.2.2.10	X	n. a.	X	n. a.
System separation sections	4.2.2.11	X	n. a.	X	n. a.
Quality of current collection	4.3.2.3	X	n. a.	X	n. a.
Space for uplift	4.3.2.3	X	n. a.	X	n. a.
Voltage and frequencies	4.1.1	X	n. a.	n. a.	X
Mean useful value of the voltage on a supply area	4.3.1.1	X	n. a.	n. a.	X
Type of line(performance)	4.3.1.1,	X	n. a.	X	n. a.
	4.3.2.1				
Protection against electric shock	4.3.1.8,	X	X	X	n. a.
	4.3.2.4				
Electrical protection (coordination with rolling stock subsystem)	4.2.2.8	X	n. a.	X	n. a.
Regenerative braking	4.3.1.4	X	n. a.	n. a.	n. a.

**▼ B**

1		2	3	4	5
Characteristics to be assessed		Assessment in the following phase			
		Design and development phase	Production phase		
Characteristic	Point	Design review	Construction, assembling, mounting	Assembled, before putting into service	Validation under full operating conditions
Maintenance	4.3.1.9, 4.3.2.6	n. a.	n. a.	X	n. a.
Isolation of power supply in case of danger	4.3.1.10	X	n. a.	n. a.	n. a.
Continuation of power supply	4.3.1.11	X	n. a.	n. a.	X
n. a.: not applicable.					

**▼ M1***ANNEX D***REGISTER OF INFRASTRUCTURE, INFORMATION ON THE ENERGY SUBSYSTEM**

The data to be provided for the registers provided for in Articles 34 and 35 of Directive 2008/57/EC of the European Parliament and of the Council <sup>(1)</sup> are those indicated in indicated in Commission Implementing Decision 2011/633/EU of 15 September 2011 on the common specifications of the register of railway infrastructure <sup>(2)</sup> and Commission Implementing Decision 2011/665/EU of 4 October 2011 on the European register of authorised types of railway vehicles <sup>(3)</sup>.

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<sup>(1)</sup> OJ L 191, 18.7.2008, p. 1.

<sup>(2)</sup> OJ L 256, 1.10.2011, p. 1.

<sup>(3)</sup> OJ L 264, 8.10.2011, p. 32.



## ANNEX E

COORDINATION OF ELECTRICAL PROTECTION SUBSTATIONS/  
TRACTION UNITS

## E.1. GENERAL

Compatibility of protective systems between traction unit and substation shall be verified.

## E.2. PROTECTION TOWARD SHORT CIRCUITS

Every traction unit is equipped with a circuit breaker whose breaking capacity is higher or lower than the maximum short circuit current that may occur on the 'primary' of its electrical circuit, depending on the traction system.

Table E.1

## Maximum contact line — rail short circuit level

Power supply system	Substation generally connected in parallel	Maximum rail short circuit current that may occur
	Yes/No	kA
AC 25 000 V-50Hz	N	15 <sup>(1)</sup>
AC 15 000 V-16,7 Hz	Y	40
DC 3 000 V	Y	50 (prospective sustained) <sup>(2)</sup>
DC 1 500 V	Y	75 (prospective sustained) <sup>(2)</sup>
DC 750 V	Y	65 (prospective sustained) <sup>(2)</sup>

<sup>(1)</sup> The value of 12 kA was previously commonly accepted.

<sup>(2)</sup> For definition see EN 50123-1

Table E.2

## Action on circuit breakers when internal fault within a traction unit occurs

Power supply system	When any internal defect fault occurs within the traction units: sequence of tripping of:	
	substation feeder circuit breaker	traction unit circuit breaker
AC 25 000 V-50 Hz	Immediate tripping <sup>(1)</sup>	Immediate tripping
AC 15 000 V-16,7 Hz	Immediate tripping <sup>(1)</sup>	<i>Primary side of the transformer:</i> tripping shall be staged <i>secondary side of the transformer:</i> immediate tripping

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Power supply system	When any internal defect fault occurs within the traction units: sequence of tripping of:	
	substation feeder circuit breaker	traction unit circuit breaker
DC	immediate tripping <sup>(2)</sup>	immediate tripping

<sup>(1)</sup> The tripping of the circuit breaker should be very rapid for high short circuits currents.

<sup>(2)</sup> When the current of the short circuit is very high, the tripping of circuit breakers in the substations should be very rapid, and thereby prevents the traction unit circuit breaker clearing faults on it.

### E.3. AUTO-RECLOSING OF ONE OR MORE SUB-STATION CIRCUIT BREAKERS.

The auto reclosing systems (if any) for circuit breakers in the sub-station are liable to re-energise the line. In such a case, the sub-station circuit breakers may only be re-closed after the tripping of the circuit breakers on the traction units present in the zone supplied by the sub-station. The traction unit circuit breakers shall trip automatically as explained in point E 4 hereafter.

### E.4. EFFECT OF LOSS OF LINE VOLTAGE AND RE-ENERGISATION ON THE TRACTION UNIT

The traction unit circuit breakers shall trip automatically within three seconds after loss of line voltage.

*Note 1:* see Annex N to this TSI.

On re-energisation, the traction unit circuit breaker shall not reclose within three seconds of the line being re-energised.

*Note 2:* the time delay on re-energisation allows for testing of the line for persistent short circuit.

### E.5. DC ELECTRIFICATION SYSTEMS: TRANSIENT CURRENT DURING CLOSURE

This provision is only applicable to DC traction units fitted with an input filter.

When the circuit breaker of a traction unit is going to be closed, with the input filter (if fitted), the transient current should not cause the protection devices in the sub-stations to trip unnecessarily. The requisite information shall be obtained from the railways concerned when vehicle-mounted filters are being designed.

The di/dt differential of the transient current on closure of the traction unit circuit breaker shall have the following characteristics:

*Table E.3*

#### **di/dt when closure of traction unit circuit breaker**

T	condition applicable to di/dt
0 ms	di/dt < 60 A/ms
20 ms	di/dt < 20 A/ms

with a minimum overhead and sub-station inductance of 2 mH.



## ANNEX F

### TYPE OF LINE

#### F.1. SCOPE

This Annex covers both:

- lines generally equipped for speeds of 250 km/h and above, and
- lines upgraded for speeds of approximately 200 km/h.

#### F.2. OBJECTIVES

This Annex defines the type of line of a route as a function of the traffic in terms of speed and headway and the traction unit power at the pantograph.

#### F.3. DEFINITIONS

##### *Type of line*

Classification of lines as a function of the parameters described below.

##### *Maximum line speed*

Speed in km/h for which the line was approved for operation.

##### *Power of train at the pantograph*

Maximum continuous power in MW demanded by the train taking into account power for traction (from effort/speed curve), regeneration and auxiliaries.

##### *Minimum possible headway*

Interval in minutes at which trains can run in impaired scheduling conditions, as allowed by the signalling system.

#### F.4. DATA FOR TYPES OF LINES

##### F.4.1. General

Table F.1 provides information common to all electrification systems.

For high-speed lines the following is assumed:  $V \geq 250$  km/h; the electrification systems chosen are AC 25 kV 50 Hz and AC 15 kV 16,7 Hz.

For upgraded and connecting lines, Table F.1 covers all the electrification systems in use in Europe, regardless of line speed.

*Table F.1*  
**Type of lines**

Range of speed V	Minimum possible headway	Train power at the pantograph	Type of line	
km/h	Minutes	MW		
$V \geq 300$	3	20-25 or more	I	a
	3	15-20		b
	3	10-15		c

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Range of speed V	Minimum possible headway	Train power at the pantograph	Type of line	
km/h	Minutes	MW		
$250 \leq V < 300$	2	20	II	a
	3	15-20		b
	3	10-15		c
	4	15-20		d
	4	10-15		e
	5	15-20		f
	5	10-15		g
$200 \leq V < 250$	2	15	III	a
	3	10-15		b
	4	10-15		c
	5	10-15		d
$160 \leq V < 200$	2	6-10	IV	a
	2	10-15		b
	2	15-25		c
	3	6-10		d
	3	10-15		e
	4	6-10		f
	4	10-15		g
	5	6-10		h
	5	10-15		i
120-160	2	<sup>(1)</sup>	V	a
	3			b
	4			c
	5			d
< 120	2	<sup>(1)</sup>	VI	a
	3			b
	4			c
	5			d

<sup>(1)</sup> For lines with speed below 160 km/h the type of line shall only be defined simply in terms of line speed and headway due to the wide range of power of trains circulating on these lines.

**▼B***ANNEX G***POWER FACTOR OF A TRAIN****G.1. SCOPE**

This Annex applies to trains designed for interoperable traffic on lines of the trans-European high-speed rail system.

**G.2. GENERAL**

The higher the power factor, the better is the power supply performance, therefore, the following rules apply. Capacitive or inductive power from a train can be utilised to change and improve the overhead line voltage.

**G.3. DEFINITION OF POWER FACTOR**

The total power factor  $\lambda$  is defined by

$$\lambda = \alpha \cos \varphi$$

where:  $\alpha$  = is the deformation factor and

$\varphi$  = the phase angle.

**G.4. INDUCTIVE POWER FACTOR****G.4.1. Objective**

This point deals with inductive power factor and power consumption over the range of voltage between  $U_{\min 1}$  and  $U_{\max 1}$  defined in Annex N to this TSI.

**G.4.2. Requirements**

For each interoperable train running on an interoperable line the requirements specified in Table G.1 shall be met.

*Table G.1*

**Total power factor  $\lambda$  of a train**

Power consumption of a train MW	Category of line		
	High-speed	Upgraded	Connecting <sup>(1)</sup>
(a) $P > 6$	$\geq 0,95$	$\geq 0,95$	$\geq 0,95$ <sup>(2)</sup>
(b) $2 < P \leq 6$	$\geq 0,93$	$\geq 0,93$	$\geq 0,93$ <sup>(2)</sup>
(c) $0 \leq P \leq 2$	<sup>(3)</sup>	<sup>(3)</sup>	<sup>(3)</sup>

<sup>(1)</sup> These values are recommended.

<sup>(2)</sup> In order to control the total power factor of the auxiliary load of a train during coasting phases, the overall average  $\lambda$  (traction and auxiliaries) defined by simulation and/or measurement shall be higher than 0,85 over a complete timetable journey.

The calculation of overall average  $\lambda$  for a train journey is taken from the active energy  $W_P$  (MWh) and reactive energy  $W_Q$  (MVarh) given by a computer simulation of a train journey or metered on an actual train

$$\lambda = 1/\sqrt{1 + (W_Q/W_P)^2}$$

<sup>(3)</sup> The adjudicating entity may impose conditions, e.g.: economic, operating, power limitation, for acceptance of trains having power factors below the target value.



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For yards or depot, when a train is stationary, with traction power off, and the active power taken from the overhead line is greater than 10 kW per vehicle, the total power factor resulting from the train load shall not be less than 0,8, but with a target value of 0,9.

The values of conditions (a) and (b) shall be checked or measured with a feeding system not limiting the performances of the train.

**G.5. CAPACITIVE POWER FACTOR**

Within the range of voltage  $U_{\min 1}$  to  $U_{\max 1}$  defined in Annex N to this TSI, capacitive power factors are not limited. Within the range of voltage  $U_{\max 1}$  to  $U_{\max 2}$ , a train shall not behave like a capacitor.

**▼B***ANNEX H***OVERHEAD LINE EQUIPMENT, GEOMETRICAL INTERACTION OF  
OVERHEAD LINES AND PANTOGRAPH, AC SYSTEMS****H.1. SCOPE**

This Annex covers:

- geometrical requirements for overhead contact lines,
- geometrical requirements for pantographs, and
- requirements for interaction of overhead contact lines and pantographs,

for lines of the trans-European high-speed rail system supplied by AC systems.

**H.2. OBJECTIVES**

This Annex supplements the basic parameters specified for lines supplied by AC systems. These requirements are necessary to guarantee safe running of the trains, a supply without interruption and undue disturbances, and to achieve an interaction without excessive wear and tear of contact wires and collector strips.

**H.3. GEOMETRICAL REQUIREMENTS****H.3.1. Overhead contact lines**

In Table H.1 the geometrical requirements are given together with tolerances.

*Table H.1***Geometry of overhead contact lines**

No	Description	Connecting lines	Upgraded lines	High-speed lines
1	Height of contact wire			
1.1	Nominal height of contact wire (mm)	Between 5 000 and 5 750 <sup>(1)</sup> <sup>(2)</sup>	Between 5 000 and 5 500 <sup>(1)</sup>	5 080 or 5 300
1.2	Tolerance (mm)	± 30	± 30	0 + 20
1.3	Limit values	4 950 and 6 200	4 950 and 6 200	—
2	Permissible contact wire gradient in relation to the track and permissible variation of gradient	See EN 50119, version 2001, point 5.2.8.2		No planned gradients acceptable
3	Permissible lateral deflection of the contact wire under action of cross wind (mm)	≤ 400		

<sup>(1)</sup> For connecting lines with mixed freight and passenger traffic of operation of trailers with oversized gauge the contact wire height may be higher provided the pantograph is suited to collect the current with the specified quality and the development of the pantograph is sufficient as specified in point 5.3.2.5.

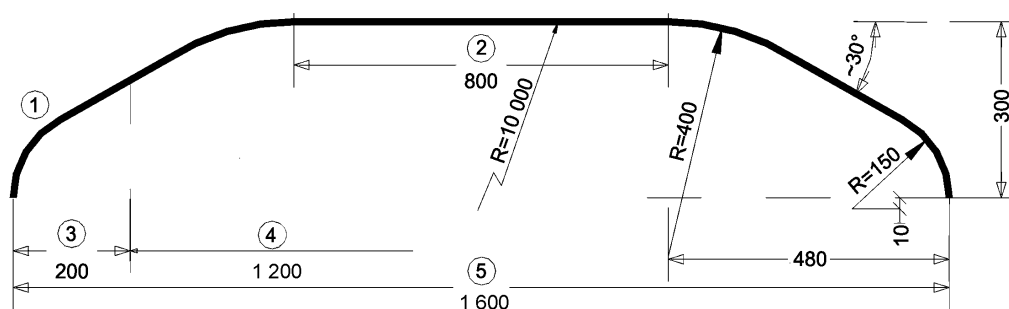
<sup>(2)</sup> At level crossings the contact wire height shall be designed according to national directives.

▼ **B****H.3.2. Pantographs**

In Table H.2 the geometrical requirements for a pantograph suitable for the trans-European high-speed rail system are presented. Figure H.1 shows details of the pantograph collector head. Since the pantographs will be used on all lines of the interoperable system no distinction between line categories can be made.

*Table H.2***Geometry of pantograph collector head**

No	Description	All line categories
1	Width of pantograph collector head (mm)	1 600
2	Working range of pantograph collector head (mm)	1 200
3	Electrical width of pantograph collector head maximum (mm)	650
4	Length of contact strips (mm)	$\geq 800$
5	Profile of pantograph collector head	See figure H.1
6	Device to detect defects in pantograph collector head	Necessary

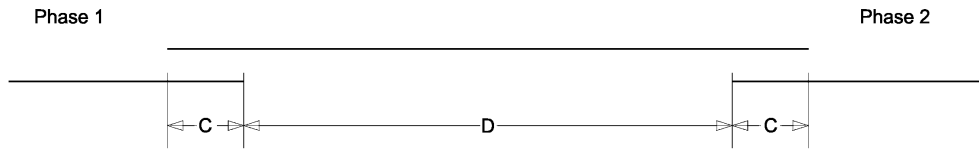
*Figure H.1***Profile of pantograph collector head**

- 1 Horn made of insulating material
- 2 Minimum length of the contact strip
- 3 Projected length
- 4 Working range of the collector head
- 5 Width of the collector head

**H.3.3. Phase separation sections**

Two types of phase separation section are discussed.

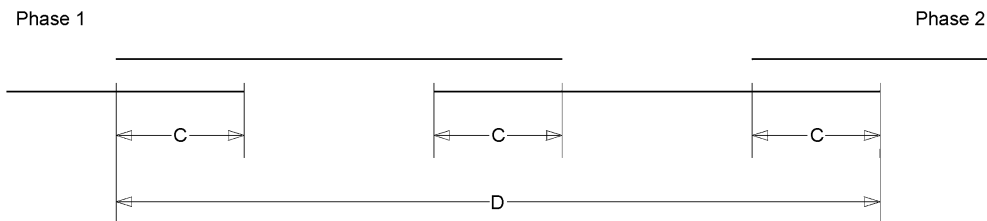
In case of the arrangement according to figure H.2 the neutral section is longer than the distance between the farthest pantograph in operation on an interoperable train which is 400 m.

**▼ B***Figure H.2***Arrangement of phase separation with long neutral section**

Length  $D > 402$  m

Overlapping sections C: pantograph in contact with two contact wires.

In Figure H.3 the total separation section is shorter than the 143 m spacing between three consecutive pantographs.

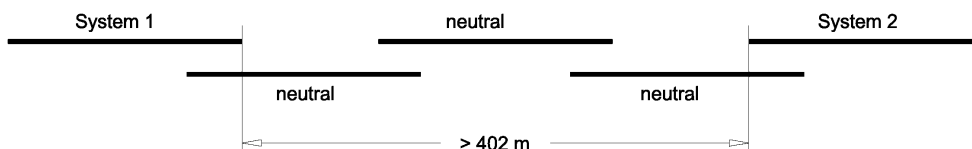
*Figure H.3***Arrangement of phase separation with short neutral section**

Length  $D < 142$  m

Overlapping sections C: pantograph in contact with two contact wires.

**H.3.4. Example of system separation section**

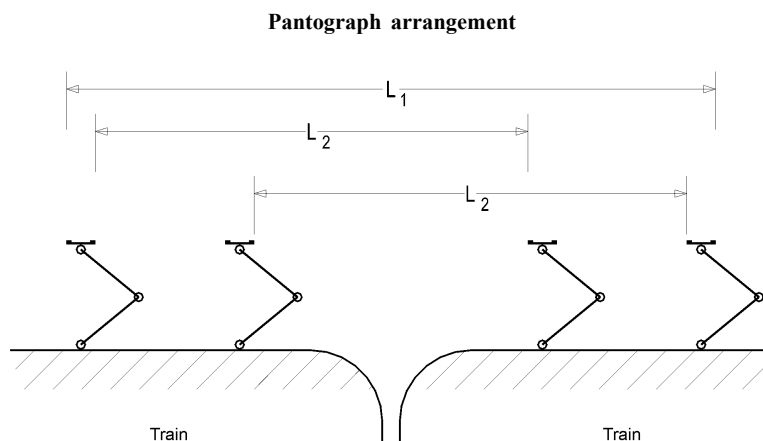
When system separation sections are negotiated with pantographs lifted the separation section consists of three neutral contact line sections insulated to each other. The total length shall be at least 402 m. Figure H.4 shows the design principle.

*Figure H.4***Arrangement of system separation section with long neutral section****H.3.5. Arrangement of pantograph on trains**

To negotiate the specified types of phase separations the maximum spacing of pantographs is 400 m, which is the maximum train length. In addition the spacing of three constructive pantographs must be more than 143 m. The pantograph between two others can be arranged anywhere. Between pantographs in service no electrical link may exist. Figure H.5 shows the pantograph arrangement.



Figure H.5



Length  $L_1 < 400$  mm

Length  $L_2 > 143$  m.

### H.3.6. Dynamic envelope for pantograph passage

Figure H.6 shows the dimensions for the space necessary for passage of Euro pantographs on interoperable lines. In addition to this space the infrastructure shall take account of the space necessary for installation of the contact line itself and the necessary safety clearances. The space depends on the design of individual contact line and the corresponding voltage.

In figure H.6 the width  $L_1$  refers to the contact wire height of 5,0 m while  $L_2$  depends on the contact wire height as applicable for a specific line.  $S$  is the provision for uplift corresponding to two times  $S_0$  according to Tables 4.5 and 4.6.

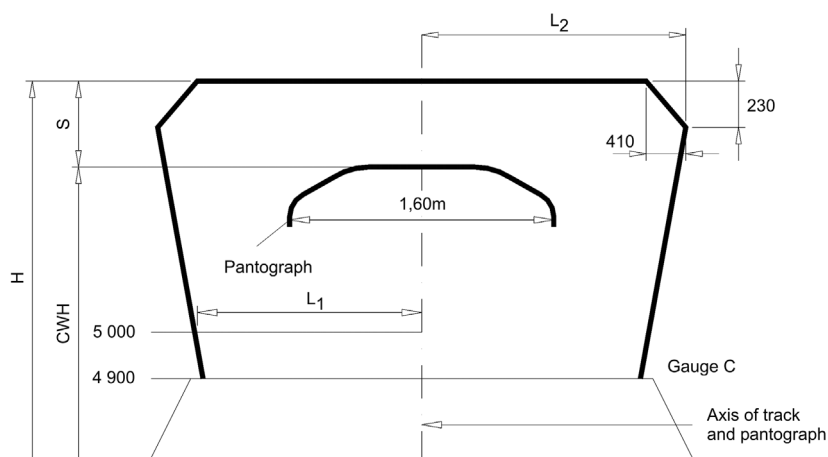
The value  $L_2$  is

$$L_2 = 0,74 + 0,04 \cdot H + 0,15 \cdot H \cdot C - 0,075 \cdot C + 2,5 / R,$$

where the maximum track gauge is assumed to be 1,45 m The cant  $C$ , the radius  $R$  and the dimension  $H$  are measured in metres.

Figure H.6

### Dynamic envelope for passage of pantographs on interoperable lines



**▼B**

Table H.3 shows as an example the relations between track radius, cant and dimensions  $L_1$  and  $L_2$  for high-speed lines with a track radius of more than 3 000 m. The dimension H is the sum of the contact wire height CWH and the provision S for uplift.

*Table H.3*

**Dimensions for dynamic envelope for pantograph passage for high-speed lines (examples, track radius more than 3 000 m)**

Cant C m	Width $L_1$ at 5,00 m height m	Width $L_2$ (see figure H.6) m
0,0	0,94	0,74 + 0,04 H
0,066	0,99	0,74 + 0,05 H
0,180	1,08	0,73 + 0,07 H

**▼B***ANNEX J***OVERHEAD LINE EQUIPMENT, GEOMETRICAL INTERACTION OF  
OVERHEAD LINES AND PANTOGRAPHS, DC SYSTEMS****J.1. SCOPE**

This Annex covers:

- geometrical requirements for overhead contact lines,
- geometrical requirements for pantographs and
- requirements for interaction of overhead contact lines and pantographs,

for upgraded and connecting lines of the trans-European high-speed rail system supplied by DC systems.

**J.2. OBJECTIVES**

This Annex supplements the basic parameters specified for lines supplied by DC systems. These requirements are necessary to guarantee the safe running of trains by an energy supply without interruption and undue disturbances and to achieve an interaction without excessive wear and tear of contact wires and collector strips.

**J.3. GEOMETRICAL REQUIREMENTS****J.3.1. Overhead contact lines**

In Table J.1 the geometrical requirements are listed together with tolerances.

*Table J.1***Geometry of overhead contact lines**

No	Description	Connecting lines	Upgraded lines
1	Height of contact wire		
1.1	Standard height of contact wire (mm)	Between 5 000 and 5 600 <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>	Between 5 000 and 5 500 <sup>(3)</sup>
1.2	Tolerance (mm)	0 + 60	0 + 60
1.3	Limit values (mm)	4 950 and 6 200 <sup>(5)</sup>	4 950 and 6 200
2	Permissible contact wire gradient in relation to the track and variation of gradient	See EN 50119, version 2001, point 5.2.8.2	
3	Permissible lateral deflection to the contact wire under action of cross wind (mm)	≤ 400	

<sup>(1)</sup> For connecting lines with mixed freight and passenger traffic of operation of trailers with oversized gauge the contact wire height may be higher provided the pantograph is suited to collect the current with the specified quality and the development of the pantograph is sufficient as specified in point 5.3.2.5.

<sup>(2)</sup> At level crossings the contact wire height shall be designed according to national directives.

<sup>(3)</sup> For the lines in Italy referred to in note 2 to Table 4.1 the contact wire height is between 5 000 mm and 5 300 mm. The other values apply to other types of lines.

► **MI** ◀

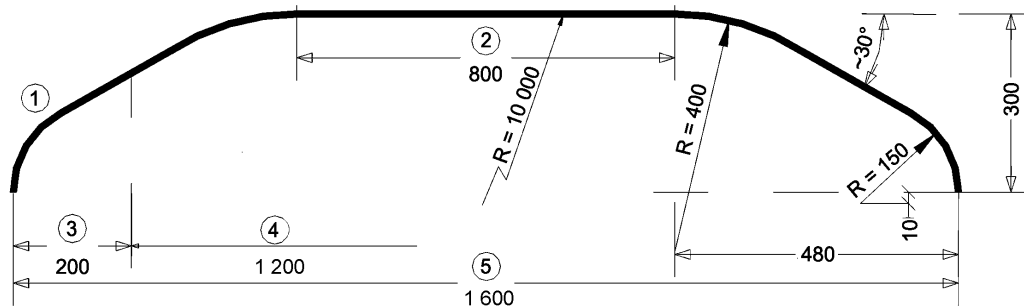
<sup>(5)</sup> For connecting lines in Spain: 4 600 mm and 6 200 mm.

**▼B****J.3.2. Pantographs**

In Table J.2 the geometrical requirements for a pantograph suitable for the trans-European high-speed rail system are presented. Figure J.1 shows details of the pantograph collector head. Since the pantographs will be used on connecting and upgraded lines of the interoperable system no distinction between line categories is made.

*Table J.2***Geometry of pantograph collector head**

No	Description	All line categories
1	Width of pantograph collector head	
1.1	Unified collector head (mm)	1 600
1.2	Collector head during transition period (mm)	1 450 and 1 950
2	Working range of pantograph collector head (mm)	1 200
3	Length of contact strips (mm)	$\geq 800$
4	Profile of pantograph collector head	
4.1	Profile of unified collector head	See figure J.1
4.2	Profile of transitional collector head	EN 50367
5	Electrical link between pantograph	When such link exists, a means to interrupt this link shall be provided
6	Device to detect defects in pantograph collector head	Necessary

*Figure J.1***Profile of current collector head**

- 1 Horn made of insulating material
- 2 Minimum length of the contact strip
- 3 Projected length



**▼B**

- 4 Working range of the collector head
- 5 Width of the collector head

**J.3.3. Dynamic envelope for pantograph passage**

The stipulations in DC are the same as in AC. Reference is made to Annex H, point H.3.6.

*ANNEX K***REGENERATIVE BRAKING****K.1. SCOPE**

This Annex applies to interoperable traffic on lines which power supply is an AC system. It gives the conditions for use of regenerative braking on power supply traction systems.

*Note:* In DC systems, by request of the railway undertaking, the adjudicating entity can decide upon the acceptance of regenerative braking.

**K.2. ROLLING STOCK CONSIDERATIONS**

Trains shall not continue to use their regenerative brake if:

- there is a loss of supply voltage or a contact line - rail/earth short circuit on the section fed by the substation,
- the contact line fails to absorb the energy,
- the line voltage is higher than  $U_{\max 2}$ . See Annex N to this TSI.

If feedback energy absorption by other consumers is not available, rolling stock shall revert to other brake systems.

**K.3. ENERGY SUBSYSTEM CONSIDERATIONS**

The energy subsystem has to be designed in such a way that regenerative braking can be used as a service brake.

The adjudicating entity shall ask the power supply authority to accept the feedback of braking energy into the supply network, when the energy cannot be absorbed by other railway consumers.

**K.4. ASSESSMENT**

The substation control and protection devices shall allow feed back for energy to the supplying net. The connecting diagrams shall allow the assessment.



## ANNEX L

### VOLTAGE AT THE PANTOGRAPH (QUALITY INDEX OF POWER SUPPLY)

#### L.1. SCOPE

The aim of a design study is to define the characteristics of fixed installations. These installations should allow the most severe conditions, as specified in the timetable to be satisfied through:

- the most dense operating period in the timetable, corresponding to peak traffic,
- the characteristics of the different types of train involved, taking account of the selected traction units.

This Annex covers both:

- high-speed lines designed for speeds of 250 km/h and above, and
- lines upgraded for speeds of approximately 200 km/h.

#### L.2. OBJECTIVES

The objective is to give an indication of quality of fixed installations for electric traction. It is based on a mathematical study of voltage seen on an electrified route with trains running to the reference timetable.

The quality index  $U_{\text{mean useful}}$  is calculated by simulation and can be verified by ad hoc measurements on a critical train.

*Note:* With the aim of guaranteeing the performance levels for all trains depending on type of line, the adjudicating entity should design his equipment in such a way that the mean useful voltage at the pantograph on each train in the supplied section is sufficiently high. This does not mean that trains will not, for very short periods, be subjected to extreme voltages as defined in Annex N to this TSI.

#### L.3. DEFINITION OF MEAN USEFUL VOLTAGE

Mean useful voltage  $U_{\text{mean useful}}$  is calculated by computer simulation of a geographic zone which takes account of all trains scheduled to pass through the zone in a given period of time corresponding to the peak traffic period in the timetable. This given period of time should be sufficient to take account of the highest load on each electrical section in the geographic zone.

Account shall be taken of the electrical characteristics of the power supply installation and each different type of train in the simulation.

The fundamental voltage at the pantograph of each train in the geographic zone is analysed at each simulation time step. For AC systems, the rms of the fundamental voltage is used. For DC systems, the average is used. This time step in the simulation shall be short enough to take into account all events in the timetable.

The voltage values from the simulation are used to study:

##### 1. $U_{\text{mean useful}}$ of power supply zone

This is the mean value of all voltages analysed in this simulation and gives an indication of the quality of the power supply for the entire zone.

All trains in the geographic zone, over the peak traffic period considered, are included in this analysis whether they are in traction mode or not (stationary, traction, regeneration, coasting) at each simulation time step.

▼ **B**2.  $U_{\text{mean useful}}$  of train

This is the mean value of all voltages in the same simulation as the geographic zone study but only analysing the voltages for one particular train at each time step where the train is taking traction load (not stationary, no regeneration, no coasting).

The mean value of these voltages gives a check on the performance of each train in the simulation and, as a result, identifies the governing train, the train whose ability to accelerate is most constrained by low voltage.

## L.4. VALUES RECOMMENDED FOR MEAN USEFUL VOLTAGE AT THE PANTOGRAPH

The minimum values for mean useful voltage  $U_{\text{mean useful}}$  at the pantograph are given in Table L.1:

Table L.1

**Minimum mean useful voltage at pantograph (kV)**

Electrification system	DC 1,5 kV	DC 3 kV	AC 15 kV	AC 25 kV
Zone	1,30	2,80	14,2	22,5
Train	1,30	2,80	14,2	22,5

L.5. RELATION BETWEEN MEAN USEFUL VOLTAGE  $U_{\text{mean useful}}$  AND  $U_{\text{min1}}$ 

The designing of the power supply shall be conducted in such a way that the simulations enabling mean useful voltage  $U_{\text{mean useful}}$  at the pantograph to be computed, never generate instantaneous voltage values at the pantograph of any train lower than the limit  $U_{\text{min1}}$  from Annex N to this TSI for traffic corresponding to the type of line concerned (see Annex F to this TSI).

## L.6. SELECTION CRITERIA DETERMINING THE VOLTAGE AT THE PANTOGRAPH FOR HIGH-SPEED TRAINS

The design of fixed installations for electric traction can be obtained by simulating the critical timetable taking into account the power drawn by each train in the simulation at each time interval. Over and above aspects of calibration of equipment (transformers, overhead lines, autotransformers for  $2 \times 25$  kV and converters for DC) and compatibility with apparent performance tolerated at the high voltage connection points, the quality of the power supply constituents an important qualifying parameter for the supply scheme studied.

The characteristic curve of traction effort and speed for a traction unit changes as a function of the voltage at the pantograph. Determining the envelope of the characteristic traction effort and speed curve, under reduced voltage is achieved in relation to the nominal characteristic curve, by extrapolation over the speed range, with the proportionality coefficient being slightly lower than the voltage ratio of voltage at pantograph and nominal voltage ( $U_{\text{pantograph}}/U_{\text{nominal}}$ ).

The voltage values obtained should allow the desired performance levels to be attained. For example, in order to study electrification with 25 kV, the selection of a voltage of at least 22,5 kV makes it possible, not to drop statistically below the minimum limit of 19 kV. Voltages below 19 kV are possible in periods of abnormal traffic with trains on closer headway in particular, or in the case of special situations that do not always appear in the simulations such as coincidence of flights of traffic in both directions.

## ▼ B

The incidence of situations with impaired performance, both from the point of view of the power supply scheme and the operating graph, should be assessed taking into account permitted reductions in performance.

The selection of the correct mean useful voltage presents the following advantages.

- It allows the traction units to function close to their nominal voltage, hence optimising efficiency and performance.
- It ensures that the values of minimum voltage specified by the standards are respected.
- It reflects the fact that the fixed installations for electric traction have the correct performance and that, as a result, increased traffic volumes can be considered.
- It allows certain impaired traffic situations to be dealt with.

### L.7. CALCULATION OF MEAN USEFUL VOLTAGE AT THE PANTOGRAPH

The mean useful voltage  $U_{\text{mean useful}}$  at the pantograph is defined as follows:

$$U_{\text{mean useful}} = \left( \sum_{j=1}^n \frac{1}{T_j} \int_0^{T_j} U_p \cdot |I_{pj}| dt \right) \cdot \left( \sum_{j=1}^n \frac{1}{T_j} \int_0^{T_j} |I_{pj}| dt \right)^{-1}$$

where:

$T_j$  = integration or study period on train number  $j$ ,

$n$  = number of trains considered in the study.

For AC systems:

$U_{pj}$  = momentary rms voltage at power frequency at the pantograph of train number  $j$ ,

$|I_{pj}|$  = module of momentary rms current at power frequency flowing through the pantograph of train number  $j$ .

For DC electrification:

$U_{pj}$  = momentary average DC voltage at the pantograph of train(s) number  $j$ ,

$|I_{pj}|$  = module of momentary average DC current flowing through the pantograph of train number  $j$ .

This represents the relation between mean power calculated for the train (trains) during their traction sequences and the corresponding mean current.

An equivalent result is obtained with the following formula that is more suitable for some computer programs:

$$U_{\text{mean useful}} = \frac{1}{n} \sum_{i=1}^n \frac{1}{MN\Delta t} \sum_{j=1}^N \sum_{k=1}^M U_{j,k}(t) \cdot \Delta t$$

where:

$n$  = number of trains considered in the simulation,

**▼ B**

$U_{j,k}$  = rms voltage of the power frequency voltage evaluated from the basic calculation step for AC electrification systems;

average voltage obtained on the basic calculation step for DC electrification systems,

$M$  = number of calculation steps in the integration period,

$N$  = number of integration periods in the simulation,

$\Delta t$  = time during which each step  $M$  is simulated,

*Note:*  $\Delta t$  has to be short enough to take account of all events in the timetable.

This expression for the voltage has the advantage that it reflects quite closely the quality of the power supply in the case of traffic simulations comprising a large number of trains on the railway under study.

The formula above is used to study:

A geographic part (i.e. the part of the network to be studied) in a given period of time, with account taken of all the trains passing through the part, whether they are in traction mode or not (stationary, traction, regenerating, coasting). The value of mean useful voltage  $U_{\text{mean useful}}$  therefore is an indicator of the quality of the power supply for the entire part.

The mean useful voltage at the pantograph of each train among those within the studied part of line; only the traction periods of the train are taken into account. In this case  $n$  is equal to 1 in the formula above. This value is taken to check the performance of each train in the simulation and as a result identifies the governing train.

## L.8. QUALITY INDEX OF THE POWER SUPPLY

### L.8.1. $U_{\text{mean useful}}$ (zone)

What	When	How	Acceptance condition
<i>Simulation</i>			
On a defined zone of the power supply system	After each simulation	Using the simulation results of the trains in the considered zone and calculation with definition in L.3	The value is greater than the values given in the row 'Zone' of Table L.1

### L.8.2. $U_{\text{mean useful}}$ (train)

What	When	How	Acceptance condition
<i>Simulation</i>			
For a defined train in the simulation timetable - mostly the dimensioning train	As a result of simulations	Using the simulation results of the train calculation with definition in point L.3	The value is greater than the values given in the row 'each train' of Table L.1 (TSI lines or classical lines)

**▼B****L.8.3. Relation between  $U_{\text{mean useful}}$  and  $U_{\text{min1}}$** 

What	When	How	Acceptance condition
<i>Simulation</i>			
	After each simulation	Using the simulation results of each train considered in the zone test to be made only if $U_{\text{mean useful}}$ at the pantograph is higher than the values stipulated in L.5.	Check that the voltage at the pantograph of each train is never under $U_{\text{min1}}$



## ANNEX M

### TEST AND VERIFICATION OF CONTACT STRIPS

#### M.1. SCOPE

This Annex applies to tests and verification of collector strips to be used on pantographs for interoperable high-speed traffic.

#### M.2. CONTACT STRIPS

##### M.2.1. General

The type of contact strip used shall be in accordance with following:

- current capacity,
- static force,
- contact strip material.

The material of the contact strips shall be acceptable to the adjudicating entity. Commonly used materials of contact strips are:

- plain carbon, if necessary impregnated with added material,
- copper-steel, copper alloy, copper,
- copper-clad carbon,
- sintered material.

For the use of other materials it is necessary to furnish proof that the characteristics are equal to or better than the characteristics of the recommended materials.

The operation with different contact strip material on the contact line network shall be based on an agreement between adjudicating entity and train operator.

*Note:* If mixed material for collector strips in the networks will be used, the wear of collector strips and contact wire could increase.

#### M.3. CURRENT AT STANDSTILL

##### M.3.1. Testing conditions

The heating of the contact wire by the current at standstill shall be checked for DC systems. A check for the AC systems is not necessary because of the lower current at standstill.

The test shall be carried out with one pantograph equipped with a collector head containing two collector strips.

The two collector strips shall be tested on a plane surface according to a used condition.

The pantograph shall be mounted on a traction unit. Testing shall be performed in a protected environment (in a closed workshop) in order to avoid any influences from flows of air.

Testing shall be performed under one or two contact wires equipped with temperature sensors. The temperature sensors shall be located 2 mm from the contact surface.



**▼B****M.3.2. Testing procedure**

Testing shall be performed with a static contact force according to point 5.3.2.6.

The current conveyed by the pantograph shall be related to the maximum consumption of the rolling stock with the limits specified in point 5.3.3.4.

Each test shall last for 30 minutes unless the temperature displayed by one of the sensors reaches the maximum permissible value for the contact wires. This value shall be specified by the adjudicating entity. In this case the test shall be stopped.

Current intensity and temperature shall be continually recorded.

Testing shall be deemed to be satisfactory if the maximum temperature of the contact wires after 30 minutes is not higher than the limit value stipulated.

**M.4. CURRENT AT ELECTRICAL LOAD****M.4.1. Testing conditions**

The wear of the contact strips by the current at electrical load shall be checked for DC systems. A check for AC systems is not necessary because of the lower current at electrical load.

*Testing conditions*

The pantograph shall be mounted on a traction unit whose capacity permits at least the collection of maximum electric current.

The pantograph fitted with the test collector strips shall be set in such a manner during the on-track runs and before the measurements that the worst conditions for current transmission are fulfilled.

**M.4.2. Testing procedure**

The traction unit shall haul a train of the maximum allowed mass at a speed such that the maximum current is reached.

In each configuration the maximum current intensity during the relevant measurements shall be transferred for 30 minutes.

In order to ensure that the running performance of the collector strips is sufficiently representative, 10 measuring runs shall be performed in each configuration.

It is recommended that the collector strips be replaced in each case after a cycle of 10 runs.

After each cycle the condition of the collector strips shall be inspected and the extent of wear (mm/1 000 km) determined so that their running performance can be assessed.

Testing shall be deemed to be satisfactory when no defects are detected which can impair the running performance of the collector strips and when the extent of wear complies with the running performance indicated in the TSI Energy.

**▼B***ANNEX N***VOLTAGE AND FREQUENCY OF TRACTION SYSTEMS****N.1. SCOPE**

This Annex defines the voltage and frequency and their tolerances at the terminals of the substation and at the pantograph.

**N.2. VOLTAGE**

The characteristics of the main voltage systems (overvoltages excluded) are detailed in Table N.1.

*Table N.1***Nominal voltages and their permissible limits in values and duration**

Electrification system	Lowest non-permanent voltage	Lowest permanent voltage	Nominal voltage	Highest permanent voltage	Highest non-permanent voltage
	$U_{\min 2}$ (V)	$U_{\min 1}$ (V)	$U_n$ (V)	$U_{\max 1}$ (V)	$U_{\max 2}$ (V)
DC (mean values)	400 <sup>(1)</sup>	400	600	720	800 <sup>(2)</sup>
	400 <sup>(1)</sup>	500	750	900	1 000 <sup>(2)</sup>
	1 000 <sup>(1)</sup>	1 000	1 500	1 800	1 950 <sup>(2)</sup>
	2 000 <sup>(1)</sup>	2 000	3 000	3 600	3 900 <sup>(2)</sup>
AC (rms values)	11 000 <sup>(1)</sup>	12 000	15 000	17 250	18 000 <sup>(2)</sup>
	17 500 <sup>(1)</sup>	19 000	25 000	27 500	29 000 <sup>(2)</sup>

<sup>(1)</sup> The duration of voltages between  $U_{\min 1}$  and  $U_{\min 2}$  shall not be longer than two minutes.

<sup>(2)</sup> The duration of voltages between  $U_{\max 1}$  and  $U_{\max 2}$  shall not be longer than five minutes.

— The voltage of the busbar at the substation with all line circuit breakers open shall be lower or equal than  $U_{\max 1}$ .

— Under normal operating conditions voltages shall stay within the range between  $U_{\min 1}$  and  $U_{\max 2}$ .

Under abnormal operating conditions voltages in the range  $U_{\min 1}$  to  $U_{\min 2}$  are acceptable.

**Relation  $U_{\max 1}/U_{\max 2}$** 

Each occurrence of  $U_{\max 2}$  shall be followed by a level below or equal to  $U_{\max 1}$  for an unspecified period.

**Lowest operational voltage**

Under abnormal operating conditions,  $U_{\min 2}$  is the lower limit of the overhead contact line voltage for which trains are intended to operate.

*Note:* Recommended values for undervoltage tripping:

The setting of undervoltage relays at fixed points or on board may be from 85 % to 95 % of  $U_{\min 2}$ .

**N.3. FREQUENCY**

The frequency of the 50 Hz electric traction system is imposed by the three-phase grid. Therefore, the values stated by EN 50 160 are applicable. The frequency of the 16,7 Hz electric traction system (except for synchronous-asynchronous converter) is not imposed by the three-phase grid.

**▼B**

Table N.2 gives the values applicable to both electric systems.

Table N.2

**Frequency on railway power system and their permissible limits**

Duration	Nominal frequency of the system	Railway power system supplied by:	
		an interconnected 3-phase grid	a non-interconnected 3-phase grid
95 % of a week	50 Hz	50,50 Hz	51,00 Hz
		49,50 Hz	49,00 Hz
	16,7 Hz	16,83 Hz	n.a.
100 % of a week	50 Hz	16,50 Hz	n.a.
		52,00 Hz	57,50 Hz
	16,7 Hz	47,00 Hz	42,50 Hz
		17,36 Hz	17,00 Hz
		15,69 Hz	16,17 Hz

n.a.: not applicable.

*Note:* In practice, the variation of frequency is more closely controlled in Europe than stated above.

#### N.4. TEST METHODOLOGY

##### N.4.1. Measurement of the voltage on the line

###### N.4.1.1. Rolling stock

Rolling Stock shall be tested as described in EN 50 215: 1999 point 9.15

###### N.4.1.2. Fixed installations

Where	When	How	Acceptance condition
N.4.1.2.1 Substation bus bar, line circuit breakers open, normal operating conditions	At commissioning	<ul style="list-style-type: none"> <li>— Voltage recorder for the fundamental frequency, or</li> <li>— Digital data loggers with a frequency range greater than or equal to 2 kHz.</li> </ul> Averaging over 1 second <ul style="list-style-type: none"> <li>— Measurement period 1 minute</li> </ul>	All voltage values are less than or equal to $U_{\max 1}$
N.4.1.2.2 If any voltage conditioning device is installed along the line Measure on either side of the device under no load and normal operating condition	At commissioning and operating	No load see above substation  When in operation see ad hoc measurement hereafter	No load see above substation  When in operation see ad hoc measurement hereafter

**▼ B**

Where	When	How	Acceptance condition
<p><i>N 4.1.2.3 Ad hoc measurement</i></p> <p>At the site, where problems are situated.</p>	On response to problems.	<ul style="list-style-type: none"> <li>— Voltage recorder devices for the fundamental frequency, or</li> <li>— Digital data loggers with a frequency range greater than or equal to 2 kHz averaging over 1 second</li> <li>— Measurement period minimum 1 hour maximum 1 week</li> </ul>	<ul style="list-style-type: none"> <li>— All voltage values are greater than or equal to <math>U_{\min 2}</math></li> <li>— All durations of voltages below <math>U_{\min 1}</math> are less than or equal to the duration stated in point N.2 requirement 1.</li> <li>— Average value of the voltage is between <math>U_{\min 1}</math> and <math>U_{\max 1}</math></li> <li>— All durations of voltages above <math>U_{\max 1}</math> are less than or equal to the duration stated in point N.2 requirement b.</li> <li>— All voltage values are less than or equal to <math>U_{\max 2}</math></li> </ul>

**N.4.2. Measure of the frequency on the line**

Where	When	How	Acceptance condition
<p><i>Continuous monitoring</i></p> <p>Only for networks, that are not imposed by the 3-phase grid.</p> <p>Continuous in connection with the frequency closed loop control in the generating stations or in the network control centre</p>	At commissioning and operating	<ul style="list-style-type: none"> <li>— Digital data loggers with a frequency range</li> </ul>	All frequency values are in the range of Table 2, last column.

**▼B***ANNEX O***LIMITATION OF MAXIMUM POWER CONSUMPTION****O.1. SCOPE**

This Annex gives requirements for current and power limitation devices on board traction units.

**O.2. MAXIMUM TRAIN CURRENT****▼M1**

The maximum allowable train current is given in Table O.1: the levels apply both in traction and regeneration modes.

**▼B***Table O.1***Maximum allowable train current (Amperes)**

Power supply system	High-speed line	Upgraded line	Connecting line
DC 750 V	—	—	6 800
DC 1 500 V <sup>(1)</sup>	—	5 000	5 000
DC 3 000 V	4 000	4 000	2 500
AC 15 000 V 16,7 Hz	1 700	1 000	900
AC 25 000 V 50 Hz	1 500	600	500

<sup>(1)</sup> On special lines (e.g. freight in mountain area, suburban network), these values may be exceeded.

**O.3. AUTOMATIC REGULATION**

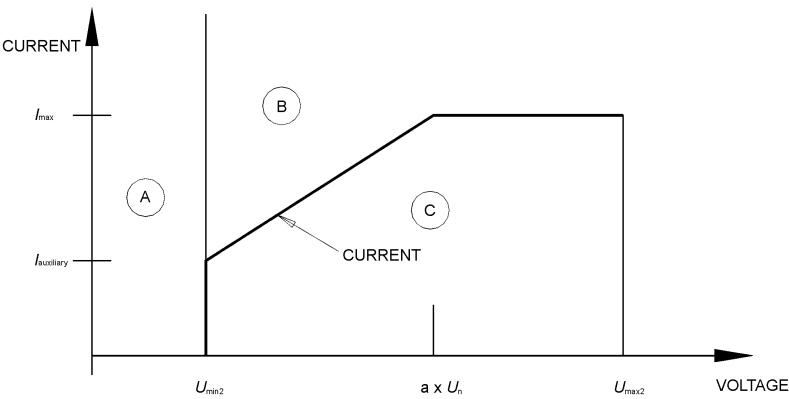
Trains shall be equipped with an automatic device that adapts the level of the power consumption depending on overhead line voltage in steady state conditions. Figure O.1 gives current as a function of the overhead contact line voltage.

This figure does not apply in regenerative braking mode.

▼ B

Figure O.1

Maximum train current against voltage



$I_{\max}$  = maximum current consumed by the train

A = no traction

B = current level exceeded

C = allowable current levels

a = factor given in Table O.2

Table O.2

Values of factor a

Power supply system	AC 25 000 V 50 Hz	AC 15 000 V 16,7 Hz	DC 3 000 V	DC 1 500 V	DC 750 V
a	0,9	0,95	0,9	0,9	0,8

O.4. POWER OR CURRENT LIMITATION DEVICE

In order to allow a powerful traction unit to operate everywhere (weak or well supplied lines), it is necessary to install on board a current or power selector which will limit the power demand of the train to the electrical capacity of the line. This is applicable only on upgraded and connecting lines of the trans-European high-speed network, and on all other lines of the conventional network.

▼ M1

▼ B

This setting can be made manually by the driver or if the line is so equipped, it shall then be done automatically.



## *ANNEX P*

### **HARMONIC CHARACTERISTICS AND RELATED OVERVOLTAGES ON THE OVERHEAD CONTACT LINE**

#### **P.1. SCOPE**

This Annex defines the necessary requirements to avoid unacceptable overvoltages on the overhead contact line caused by harmonics generated by traction units.

#### **P.2. GENERAL**

The harmonic characteristic of the power supply and the rolling stock in the railway system determines the overvoltages in the overhead contact lines. In order to achieve electrical system compatibility under steady state and dynamic conditions, those overvoltages must be limited below critical values in the relevant frequency range. With protection devices installed, overvoltages cause an interruption of normal operation and are critical more from the operation point of view than from safety aspects.

The following physical effects cause overvoltages:

#### **Overvoltages caused by system instability**

Modern railway vehicles with inverter propulsion and auxiliary systems as well as static-tie frequency converters are generally active devices which are capable of transferring energy from one frequency in the spectrum to another one. Their transfer behaviour is largely determined by the controllers as well as by the passive elements in the system.

Controllers have to be tuned in such a way that for all operating conditions stable behaviour results. In a non-stable system, physical values (as voltages or currents) either tend towards infinity and cause a protective shutdown in reality (valid for linear and non-linear systems) or continuously (steady state) oscillation on one or several frequencies (possible only in non-linear systems).

Stability questions always are related to feedback loops in a system, especially through one or several controllers of one or several electrical subsystems. There is no explicit excitation source, small disturbances are sufficient. This has to be distinguished from the other cases described below, where both an excitation source and a transmission/amplification path always exists.

Normally the potential oscillations caused by instabilities are in the frequency range of up to about 500 Hz (bandwidth of the relevant controllers). Low frequency oscillations (below and around supply frequency) strongly involve non-linear characteristics of modern vehicles, higher frequency instabilities can be linearised approximately.

#### **Overvoltages caused by harmonics**

Solid state inverters (both phase angle controlled and forced commutated ones) installed on rolling stock, or for power supply, produce current and voltage harmonics which can be represented by current or voltage sources in a simplified manner. Every type of converter generates a typical current or voltage spectrum. The converter, combined with passive elements such as transformers and filters, shows either a current source or voltage source behaviour including a typical internal impedance.

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All power supply systems include resonance, due to the resonance of transmission lines and cables, some also due to passive filter components. This leads to an amplification of harmonics injected by converters into the power supply system. An amplification (or partial suppression) occurs both at the location of the converter (due to the line impedance seen from the converter) and between the converter's location and other locations in the network (transfer behaviour of the power supply itself).

An amplification of strong harmonics may lead to significant overvoltages, either at the vehicle's location or at a completely different location in the network.

The supply system (substations and overhead contact line) has resonance peaks due to its distributed parameters — inductance and capacitance per unit of length. These resonance peaks can cause huge resonant currents and voltages. More than 100 times could be the ratio between maximum and minimum current recorded along the overhead contact line at specific resonance frequencies. For four-quadrant converter vehicles the harmonic currents at the pantograph of a vehicle can be increased about three times due to a power supply net impedance unequal to zero.

Further technical phenomena, which have to be considered for the electrical systems compatibility between power supply and rolling stock, are:

- multiple zero-crossings,
- voltage spikes and sags, transients,
- variations of the phase of supply voltage,
- low frequency oscillations.

From conducted interference point of view following effects can be relevant:

- wheel slip/slide,
- auxiliary load,
- dynamic events,
- harmonics from the auxiliary converter,
- modulations produced from different converters.

### P.3. ACCEPTANCE PROCEDURE

Any new or rebuilt traction unit or infrastructure component (for example power supply equipment, static converter, high-voltage cable) will be integrated in an existing power supply network with traction units.

Compatibility between existing traction units and existing infrastructure, and future traction units and infrastructure components has to be checked towards the phenomena described in point P.2.

Involved bodies or parties are:

- the adjudicating entity,
- the train operator(s) of existing traffic,
- the purchaser/owner of the new traction unit(s) or infrastructure equipment,
- the manufacturer of the new traction unit(s) or infrastructure equipment.



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A general specification for rolling stock or power supply, which avoids over-voltages in any situations, might be very conservative and impossible to fulfil. Therefore, a process as described in point P.6 should be applied to check compatibility (compatibility case).

**P.4. CHARACTERISATION OF THE TRACTION POWER SUPPLY  
FIXED INSTALLATIONS**

To obtain complete and in-depth characterisation of the fixed installations for power supply is a huge effort. Furthermore, a general and simple characterisation for all types of fixed installations that is appropriate for the compatibility case (point P.6) can not be given.

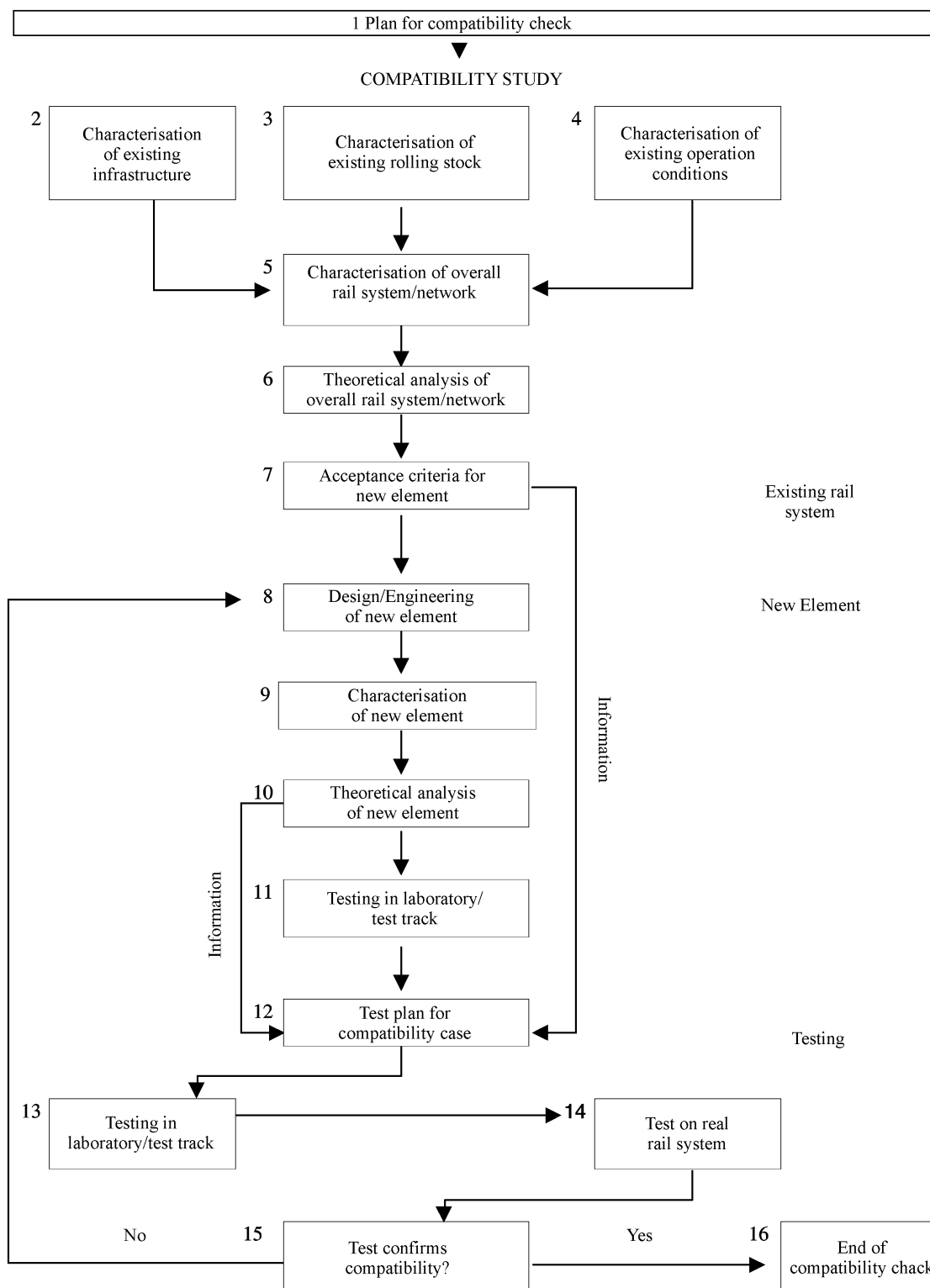
Values of systems shall be given by the adjudicating entity.

**P.5. CHARACTERISATION OF THE TRAINS**

Values of vehicles shall be given by the operator(s) of existing traffic to the adjudicating entity.

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Figure P.1:

**Procedure for introducing a new vehicle or new element**

**▼B****P.6. COMPATIBILITY STUDY**

The compatibility study (or compatibility case) is a process to demonstrate the compatibility of the new rolling stock or the new infrastructure component with the existing traction units and power supply network. As depicted in figure P.1 the first activity of the compatibility is the planning of the complete compatibility case. The flow chart is applicable for new rolling stock and also new infrastructure power supply components. It is a procedure for their introduction into an existing railway system.

The adjudicating entity is responsible for characterisation of infrastructure and overall network as described in points P.4 and P.5. It is also responsible for the definition of particular acceptance criteria for the vehicles or new infrastructure components as described in the steps 1 to 7 of Table P.1. The purchaser/owner of the new component (traction unit or power supply equipment) has to carry out a study to proof its compatibility. The particular acceptance criteria are necessary to guarantee compatibility to the complete system as described in point P.7

*Table P.1***Description of steps**

No	Title	Description	Responsible
1	Plan for compatibility check	The plan for a specific compatibility check defines the scope of the analysis, and the precise tasks and responsibilities. The plan forms an agreement between all parties involved.	Organisation in charge of the compatibility check, normally supplier of new element
2	Characterisation of existing infrastructure	Characteristics of the existing infrastructure (mainly power supply system), information relevant with for the compatibility with. Information can be provided in the form of computer models.	Adjudicating entity
3	Characterisation of existing rolling stock	Characteristics of the vehicles already operating on the network, information relevant for the compatibility with the power supply. The characteristics can be provided in the form of computer models.	Operator/owner of rolling stock
4	Characterisation of existing operating conditions	Information about the operation of the existing system: number of trains in service, typical time-tables, normal feeding arrangements, emergency feeding arrangements.	Operator of the railway system

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No	Title	Description	Responsible
5	Characterisation of overall rail system/network	This is the combination of the information from 2, 3 and 4. It may be necessary to define different scenarios.	Adjudicating entity
6	Theoretical analysis of overall system/network	Investigation of compatibility aspects for different scenarios. As a first step: confirm compatibility of the existing system. As a second step: test potential new elements (vehicles or power supply systems), check what characteristics they need to fulfil to maintain stability of the system.	Adjudicating entity
7	Acceptance criteria for new element	The result from the theoretical investigations in 6 is the particular acceptance criteria for new vehicles or new elements of the power supply system (e.g. substation transformers, high voltage cables etc). The particular acceptance criteria must be understandable and measurable when designing and testing a new element.	Adjudicating entity
8	Design/Engineering of new element	Design of new vehicles or new elements of the power supply system, considering also the acceptance criteria defined in 7.	Supplier of the new element (vehicle or power supply equipment)
9	Characterisation of new element	The new element shall be characterised with respect to its compatibility with other vehicles and power supply elements. This characteristic after validation in step 15 shall allow an amendment of the characterisation of the existing railway as required in 2 and 3.	Supplier of the new element (vehicle or power supply equipment)
10	Theoretical analysis of new element	At an early stage of the design, it shall be checked in a theoretical analysis, e.g. using computer models, that the new element can meet the acceptance criteria.	Supplier of the new element (vehicle or power supply equipment)

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No	Title	Description	Responsible
11	Testing in laboratory/on test track	Once the first equipment (vehicle or power supply equipment) is built, it shall be tested in the laboratory or on a test track to verify that it meets the acceptance criteria as predicted by the theoretical analysis in 10. This set of tests is a type test of the new element.	Supplier of the new element (vehicle or power supply equipment)
12 <sup>(1)</sup>	Test plan for compatibility case	A plan shall be made to define the tests necessary to confirm as far as possible and reasonable: <ol style="list-style-type: none"> <li>1. that the new element meets the acceptance criteria;</li> <li>2. that the compatibility criteria of the standard are met and hence that the acceptance criteria are sufficient</li> </ol>	Organisation responsible for the compatibility case
13 <sup>(1)</sup>	Testing in laboratory/on test track	As far as possible, tests will be performed in the laboratory and on test track. These tests shall officially demonstrate that the acceptance criteria are met. A failure to meet the acceptance criteria means redesign of the new equipment by the supplier.	Organisation responsible for the compatibility case
14 <sup>(1)</sup>	Tests on real rail system	Tests on the real system shall give confidence that the acceptance criteria are sufficient to guarantee stability of the system after introduction of the new elements. If these tests show compatibility problems despite the compliance of the new equipment with the acceptance criteria, this means that the acceptance criteria were not sufficient.	Organisation responsible for the compatibility case
15	Tests confirm compatibility?	If both sets of tests are successful, then compatibility of the new element with the existing system has been demonstrated. This shall be documented in a compatibility report.	Organisation responsible for the compatibility case

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No	Title	Description	Responsible
16	End of compatibility check	With the successful completion of the compatibility case, the new elements (vehicles or power supply equipment) become <sup>(2)</sup> part of the existing railway system. The responsibility for its compatibility now lies with the operator of the railway system.	Operator of the railway system

<sup>(1)</sup> The test plan will define if both steps 13 and 14 or only one we have to be performed.

<sup>(2)</sup> Seen from the compatibility point of view.

The result is a document describing the theoretical analysis and the proving tests to ensure that the vehicles and infrastructure are compatible in terms of conducted interference currents and stability.

#### P.7. METHODOLOGY AND ACCEPTANCE CRITERIA

The compatibility case, which is described in point P.5, shall demonstrate that the existing rail system and the new element(s) are compatible.

The overall criterion for overvoltages and stability is that:

- no overvoltage higher than 30kV peak for 15kV - 16,7 Hz networks and 50kV peak for 25kV - 50 Hz networks will occur on the overhead contact line in any point of the power supply network with voltage  $U$  defined in Annex N to this TSI below or equal to  $U_{\max 2}$ . This value is the peak value of the distorted voltage waveform.

These overall criteria can always be applied,

- since the overall acceptance criteria can only be applied to the complete rail system (existing rail system and new element(s)), it is beneficial to give design guidelines for the new elements which reduce the risk of failure in the compatibility study. For traction units the following guideline may be used:

The vehicle has to be passive (e.g. phase of input admittance between  $-90^\circ$  and  $+90^\circ$ ) for all frequencies equal and higher than the first (lowest) resonance frequency of the existing rail system (existing infrastructure and existing rolling stock).

The distance between the highest active frequency of the vehicle (i.e. highest frequency with a phase of the input admittance below  $-90^\circ$  or above  $+90^\circ$ ) and the lowest resonance frequency on of the existing rail system as described here above has to be larger than 20 % of the lowest resonance frequency.

**▼B***ANNEX Q***DYNAMIC INTERACTION BETWEEN PANTOGRAPH AND OVERHEAD CONTACT LINE****Q.1. SCOPE**

This Annex gives requirements and test method concerning the dynamic interaction between pantograph and overhead contact line.

**Q.2. DEFINITIONS**

*Contact force*: the vertical force applied by the pantograph to the overhead contact line. The contact force is the sum of forces for all contact points of one pantograph.

*Static contact force*: The mean vertical force exerted upward by the collector head on the overhead contact line, and caused by the pantograph-raising device, whilst the pantograph is raised and the vehicle is at standstill.

*Mean force*: the statistical mean value of the contact force.

*Maximum force*: the maximum value of the contact force.

*Minimum force*: the minimum value of the contact force.

*Overhead contact line*: a contact line placed above (or beside) the upper limit of the vehicle gauge and supplying vehicles with electric energy through roof — mounted current collection equipment (IEC 50 811-33-02).

*Arcing*: the flow of current through an air gap between a contact strip and a contact wire usually indicated by the emission of intense light (pr EN 50 317).

*Percentage of arcing*: this is given by the following formula:

$$NQ = \frac{\sum t_{arc}}{t_{total}} \cdot 100$$

The result, given in %, is a characteristic for a given speed of the vehicle (prEN 50317).

*Pantograph head*: pantograph equipment comprising the contact strips and their mountings

*Contact point*: point of mechanical contact between a contact strip and a contact wire

*Aerodynamic force*: additional vertical force applied to the pantograph as a result of air flow around the pantograph assembly

*Quasistatic force*: sum of static force and aerodynamic force at the particular speed

*Tension length*: distance from one termination point of the overhead contact line to the next (EN 50 119)

*Control section*: representative part of the total measuring length, over which the measuring conditions are controlled

*Pantograph current*: current that flows through the pantograph

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## Q.3. SYMBOLS AND ABBREVIATIONS

$\sigma_{\max}$	maximum standard deviation of contact force
$F_m$	mean force
$F_{\max}$	maximum force
$F_{\min}$	minimum force
$NQ$	percentage of arcing
$d$	is the distance between arc sensor and light source (contact strip)
$y$	is the calibration distance between arc sensor and light source
$x$	is the power density of the smallest arc that can be detected
$F_{\text{applied}}$	is the force applied to pantograph head
$F_{\text{measured}}$	is the force measured
$n$	is the number of frequency steps
$f_1$	is the minimum frequency
$f_n$	is the maximum frequency
$f_i$	is the actual frequency

## Q.4. INTERACTION PERFORMANCE

## Q.4.1. Mean contact force for intermediate period

Figure Q.1

## Adjustment curve C1

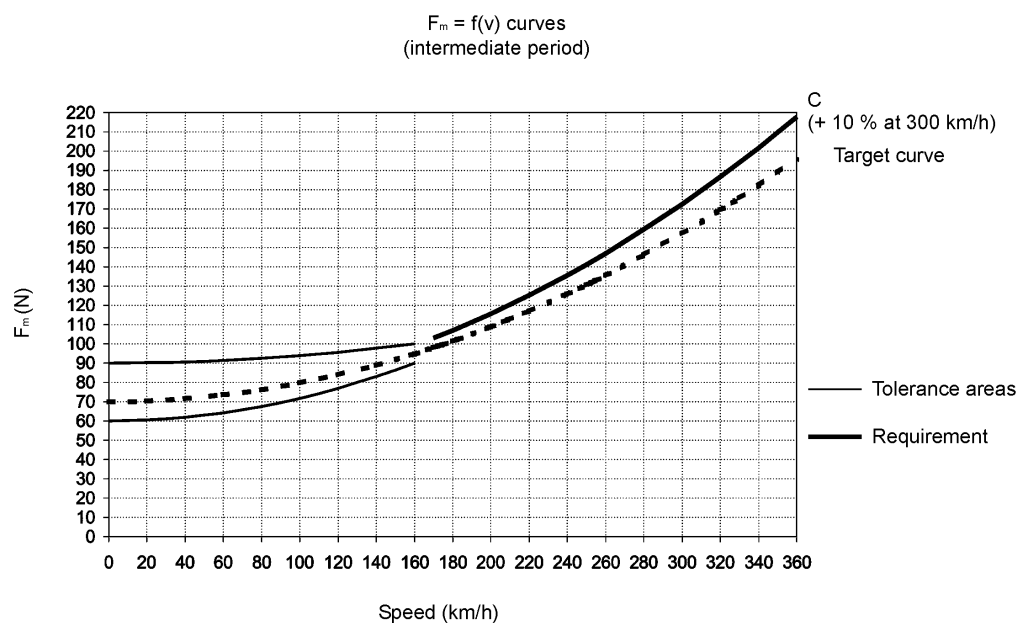
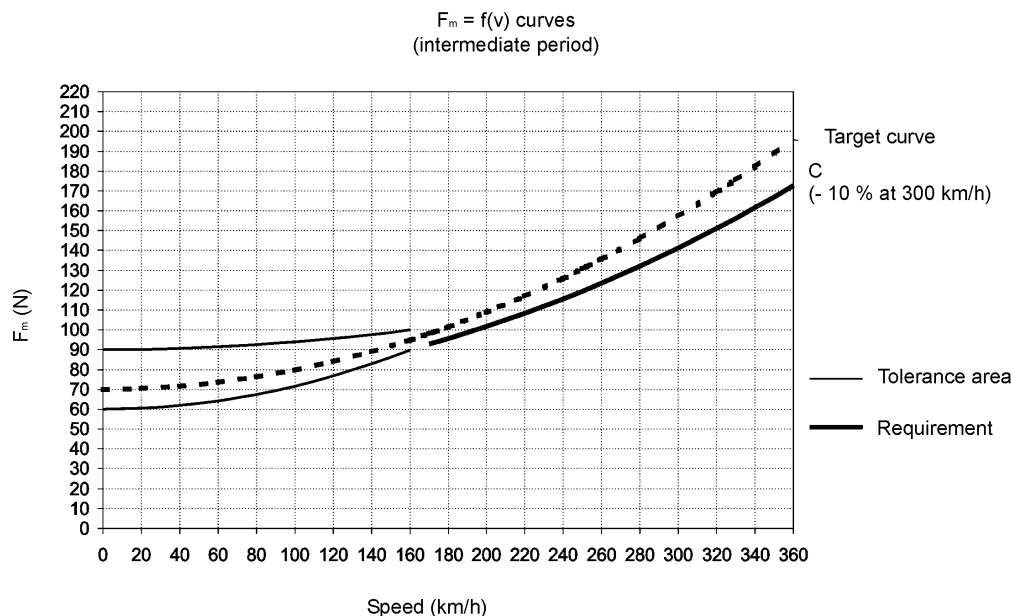






Figure Q.2

## Adjustment curve C2



#### Q.4.2. Requirements for output and validation of measurements of the dynamic interaction between pantograph and overhead contact line

##### Q.4.2.1. General

The measurement of the interaction of the contact line and the pantograph is intended to prove the safety and the quality of the current collection system. Results of measurements of different current collection systems shall be comparable, to approve components for free access within Europe.

*Note:* Measured values are also required for validation of simulation programs and other measurement systems.

To check the performance capability of the current collection system at least the following data shall be measured:

- the contact force or percentage of arcing,
- the contact wire uplift at the support as the pantograph passes.

In addition to the measured values, the operating conditions (train speed, location, etc.) shall be recorded continuously and the environmental conditions (rain, ice, temperature, wind, tunnel, etc.) and test configuration (parameters and arrangement of pantographs, type of overhead contact system, etc.) during the measurement shall be recorded in the test report. This additional information shall ensure a repeatability of the measurement and a comparability of the results.

##### Q.4.2.2. Measurements of contact force

###### General requirements

The measurement of contact force shall be carried out on the pantograph with force sensors. The force sensors shall be located as near as possible to the contact points.

The measurement system shall measure forces in the vertical direction, without interference from forces in other directions.

The measurement deviation of the force sensors caused by the temperature shall be less than 10 N (for the sum of the force of all sensors) under all measuring conditions.

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For pantographs with independent contact strips each contact strip shall be measured separately.

The measurement system shall be immune to electromagnetic interference.

The maximum error of the measurement system shall be less than 10 %.

*Influence of the measurement system*

The measurement system shall not have any effects on the measured force which could change the result by more than 5 %.

*Note:* The most important influence for distortion of the result by the measurement system are aerodynamic forces on the measurement equipment. This distortion can be checked by carrying out aerodynamic tests with and without the measurement system.

*Inertia correction*

The inertia forces due to the effect of the mass between the sensors and the contact point shall be corrected.

*Note:* This can be done by measurement of the acceleration to these components.

*Aerodynamic correction*

A correction shall be applied to allow for the influence of aerodynamic forces on the components between sensors and the contact points.

Aerodynamic tests shall be carried out to establish the aerodynamic corrections.

*Note:* The aerodynamic influence can be checked by a tethered test online.

Aerodynamic tests shall be carried out with nominally the same configuration (contact wire height, train configuration, measurement equipment, environmental conditions, etc.) as during the measurement of contact force.

*Note:* The aerodynamic test may be carried out during a line test.

*Calibration of the measurement system*

The measurement system shall be laboratory tested to check the accuracy of the measured force. This test shall be carried out for the complete pantograph fitted with the complete force measurement devices and any accelerometers, the data transfer system (telemetry, optical systems) and amplifiers.

The ratio between the applied and the measured forces (the transfer function of the pantograph and instrumentation) shall be determined by a dynamic excitation of the pantograph, at the pantograph head for a range of frequencies.

*Note:* If a sinusoidal force is used, an amplitude (peak to peak) of 30 % of the static force gives representative results.

The tests shall be carried out for the two cases:

— the force being applied centrally to the pantograph head,

— the force being applied 250 mm from the centre line of the pantograph head, if possible. Otherwise the point of force application shall be as close as possible to this value. If another value is used, it shall be noted in the test report.

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The test shall be carried out with the pantograph head at the height of interest.

This test shall be carried out with the mean force equal to the static force. If the pantograph contact force increases with speed, the test shall also be carried out at the maximum quasistatic force.

Measurements of the applied force and the measured force shall be taken at frequencies up to 20 Hz in 0,5 Hz steps, with reduced intervals at resonant frequencies. The frequency steps near the resonant frequencies shall be specified.

*Note:* The transfer function is a continuous function with greater variations close to the resonant frequencies. The reduction of the frequency steps near the resonant frequencies is necessary.

The accuracy of the transfer function shall be calculated by using the following formula:

$$\left( 1 - \frac{1}{(f_n - f_l)} \sum_{i=1}^{n-1} \left( (f_{i+1} - f_i) \left| 1 - \frac{F_{measured}}{F_{applied}} \right| \right) \right) \cdot 100 \%$$

The transfer function of the pantograph force measurement system shall have an accuracy of greater than 80 % up to a frequency limit of 10 Hz without any correction. This accuracy is a mandatory requirement for the measurement system.

For the use for measurement of dynamic interaction between pantograph and overhead contact system the accuracy of the transfer function of the measurement systems shall be greater than 90 % up to a frequency limit of 20 Hz (in accordance with the general requirements). To achieve this a correction with filters can be made.

#### *Measurement parameters*

The sampling rate shall be greater than 200 Hz for time sampling or smaller than 0,40 m for distance sampling.

The contact force shall be low pass filtered with a cut-off frequency of 20 Hz.

The measuring range shall be at least:

- for AC-pantographs: from 0 N to 500 N,
- for DC-pantographs: from 0 N to 700 N.

#### *Measurement results*

Measurements taken within a control section shall be evaluated.

For calculating statistical values the control section should not be shorter than a tension length.

As a minimum the following statistic values shall be calculated for a control section:

- mean value ( $F_m$ ),
- maximum value,
- minimum value,
- standard deviation ( $\sigma$ ),
- histogram or probability curve of the contact force.

**▼B****Q.4.2.3. Measurements of displacement**

The measurement system shall not have any effects on the measured displacement which could change the result by more than 3 %.

*Uplift at the support*

The error of the measurement system shall be smaller than 5 mm.

*Vertical displacement of the contact point*

The vertical displacement of the contact point is measured relative to the base frame of the pantograph.

The accuracy of the measurement system shall be better than 10 mm.

*Measurement of other displacements in the overhead contact line*

The accuracy of the measurement system shall be better than 10 % of the amplitude of the measured value or less than or equal to 10 mm, whichever gives a higher accuracy.

**Q.4.2.4. Measurement of arcing***General requirements*

For the detection of arcs the detector shall be sensitive to the wavelengths of light emitted by copper materials. For copper and copper alloyed contact wires a wavelength range shall be used, that includes the range 220 nm to 225 nm or 323 nm to 329 nm.

*Note:* These two wavelength ranges have substantial copper emissivity.

The measurement system shall be insensitive to visible light with wavelength greater than 330 nm.

The detector shall:

- be close enough to the pantograph to get a sufficiently high sensitivity,
- be close enough to the vehicle's longitudinal axis to get a sufficiently high sensitivity,
- be located behind the pantograph according to the travel direction of the vehicle,
- aim at the trailing contact strip according to the travel direction,
- be sensitive for a field of view over the whole working area of the pantograph head; the tolerance for this sensitivity shall be better than 10 %,
- have a response time to the beginning and ending of an arc of less than 100 µs,
- have a detection threshold, depending on the minimum arc energy which shall be measured.

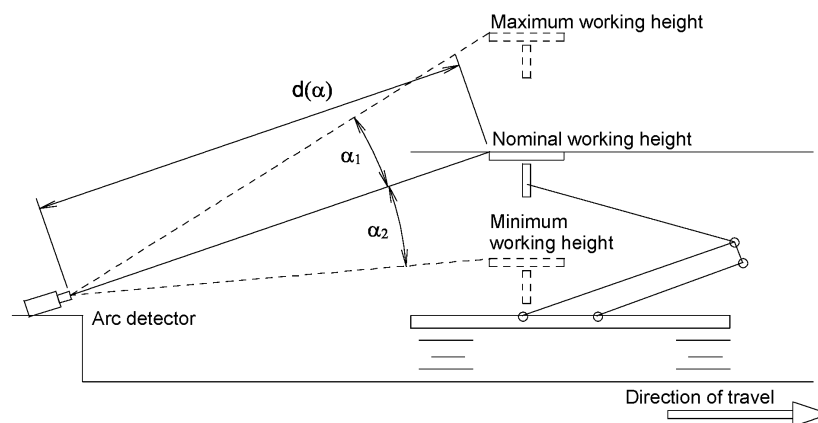
*Note:* The threshold values vary depending of the distance between measurement device and the place where the arcs occur.

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Figure Q.3 gives an example of the side view of the location of a detector.

Figure Q.3

**Detector location**



*Calibration of the arc measurement system*

The considered detector shall be calibrated in power density in spectral range of interest.

This sensitivity curve represents the relationship between the response in volts of the detector, and the power density in  $\mu\text{W}/\text{cm}^2$ . This response is measured at the analogue output of the detector.

The power density of the smallest arc which is detected shall be defined.

*Note:* For example this value shall be at 5 m:

- $160 \mu\text{W}/\text{cm}^2 + 10 \%$  under 25 kV overhead contact line,
- $12,5 \mu\text{W}/\text{cm}^2 + 10 \%$  under 1,5 kV overhead contact line.

*Adjustment of the operating distance*

If the distance between the sensor and the light source differs in operation from the calibration distance ( $y$ ), an adjustment of the detector shall be carried out.

This shall be carried out as follows:

- determine the power density of the smallest arc that can be detected at this distance in accordance the  $1/d^2$  law,
- use the calibration values to determine the signal corresponding to this power density level,
- consequently, the new value of power density threshold to be detected is a function of the new distance ( $d$ ) owing to the relation

$$x \cdot d^2 / y^2$$

*Note:* An arc is considered to be a point source and consequently the power density is proportional to  $1/d^2$  (see figure Q.3).

*Values to be measured*

As a minimum the system shall measure:

- the duration of each arc,
- the train speed during the test,
- the pantograph current.

The location of the arc along the overhead contact line (kilometric position) should be recorded.

**▼B***Representation of values*

The representation of values shall be carried out for a control section.

For the output only arcs that were lasting longer than 1 ms shall be analysed.

When analysing the measurements, parts with a pantograph current below 30 % of the nominal current of the pantograph shall be disregarded.

As a minimum for the control section the following values shall be produced:

- train speed,
- the number of arcs,
- the sum of the duration of all arcs,
- the largest arc duration,
- the total time with a pantograph current greater than 30 % of the nominal current per train per pantograph,
- the total run time for the control section,
- the percentage of arcing.

*Note 1:* Another possible criterion is the number of arcs per km with a pantograph current greater than 30 % of the nominal current.

*Note 2:* The control section should not be shorter than 10 km and should be travelled at a constant speed with a tolerance of  $\pm 2,5$  km/h.

*Note 3:* To get representative results for the overhead contact line the total time with a pantograph current greater than 30 % of the nominal current should not be shorter than the time taken to travel over one tension length. This time should not be interrupted by sections with reduced currents and the speed should be constant.