TSI Energy 2015 – Reference Parameters for Overhead Contact Lines

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Summary
The useable contact wire lateral position, determined in accordance with TSI ENE 2015 and EN 15273, based on the displacement of the pantograph in relation to the track axis, may be reduced by 16%. This reduced lateral position results in up to 8 m shorter span lengths for DB's standard contact line types and, therefore, in increased capital costs. The reasons are the reference parameters for the lateral displacement of vehicles, established for the determination of the infrastructure gauge, also provide for vehicle inclination on straight tracks, to improve reliability. These reference parameters have been empirically derived from conditions in existing railway infrastructure. However, for new installations these provisions are not necessary. The TSI Energy 2015 should be corrected such that contact line designs with proven performance over long periods can also be used in the future.

Keywords: overhead contact line, interoperability, technical specification of interoperability, energy subsystem, conventional railway, high-speed railway, mechanical kinematic gauge of pantograph, electrical kinematic gauge of pantograph

1. Introduction

The need for free access of wagons and trains within the railway systems of Europe led to a specification for an internationally valid vehicle gauge as a basis for the design of freight and passenger wagons even before the electrification of the railways started. The first version of a vehicle gauge was specified in *Technical unit within the railway system* (TE) [1] in 1913. For this TE the vehicle gauge was determined for a stationary vehicle located centrally on a track.

For the design of the infrastructure gauge no international mandatory rules existed at that time. Therefore, it was open to the individual railway managers to specify the distances between the vehicle gauge and the infrastructure gauge to be observed when constructing new lines. The first harmonization of the specification for the infrastructure gauge was initiated by the *Verein deutscher Eisenbahnverwaltungen* (Association of German Railway Entities) and summarized within the *Technical agreements on the installation and operation of main line railways and secondary railways* (TV) [16]. This formed the basis for the standard infrastructure gauge included in the *Installation and operation regulation* (BO) [2] and the *Railway installation and operation regulation* (EBO) of 1967 [4].

During the 1950s the *International Union of Railways* (UIC) prepared a harmonized international vehicle gauge. The introduction of more vehicles with softer suspension designs and higher running speeds of trains led to a transition from static considerations applied up to that period, to kinematic considerations [7]. This approach used actual running vehicle displacements which followed from real design parameters.

For this purpose working group 57A established a reference gauge which forms the interface between the vehicles and the infrastructure and therefore, enables a distinct separation between responsibilities [17]. Following the reference gauge to the inside (towards the vehicle) is the vehicle gauge with the limitation E From the reference gauge to the outside (away from the vehicle) is the infrastructure gauge by the extension G. The extension G also considers effects of the infrastructure.

The standard EN 15273 replaced the codex UIC 505 and also assumed the kinematic calculation method for the vehicle gauge, reference gauge and infrastructure gauge. The TSI ENE [13] together with the corrigendum [3] has also used

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this calculation method since coming into force on 1st January 2015 with reference values for cant, cant deficiency and flexibility. The useable contact wire lateral position on the pantograph should be determined using the calculation method given in this TSI ENE from the total movement of the pantograph, which results from the reference gauge for the determination of the infrastructure gauge and the vehicle gauge.

Prior to the new TSI ENE [13] coming into force, 0,55 m useable contact wire lateral position in straight lines and 80 m spans for standard contact lines could be designed and installed on DB AG. Applying the kinematic calculation method specified in [13] the permissible spans would be reduced by up to 8 m, due to a smaller useable contact wire lateral position (see Table 1). The reason for this reduction can be seen in the assumed values for flexibility and the reference values for cant and cant deficiency which need to be considered for the calculation of the useable contact wire lateral position and the determination of the kinematic reference gauge.

For more than 70 years 80 m long spans in straight lines at 5,5 m contact wire height have proven their reliability in operation in Germany. As examples, DB's contact line types Re100, Re160 and Re200 (Figure 1) have operated successfully on the basis of the accepted calculation approaches used before the TSE ENE [13] came into force. The calculation method according to [13] and the parameters used need to be questioned, in order to avoid the excessive reduction in span lengths and consequent increase in capital costs.

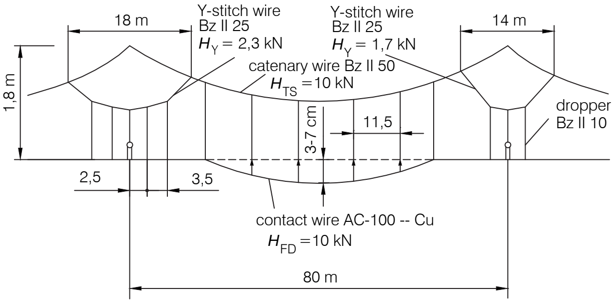

Fig. 1. Longitudinal span of DB's standard overhead contact line Re200

2. Longitudinal spans for contact lines in Germany

In 1907 the Siemens Schuckert Company (SSW) installed a contact line using 100 m long spans on the Regensdorf – Wettingen [14] test line. This contact line design formed the basis of the standard span length of 100 m in Germany. Subsequently, to contain capital costs, the Swiss railways (SBB) also adopted this design with span lengths up to 100 m on numerous lines in Switzerland. In 1931 the Deutsche Reichsbahn (DR) limited the longitudinal spans to 94 m on straight line sections for wind velocities up to 20 m/s, to 80 m for 24 m/s, to 70 m for 28 m/s and to 54 m for 31 m/s [5].

However, the interaction of contact lines and pantograph proved to be unsuitable with the longer spans at speeds above 110 km/h [15]. Besides other phenomena, large oscillations occurred within the

Table 1

Comparison of span lengths for 1 950 mm pantograph by consideration with and without reference cant (all dimensions in m)

Verification height *h*	**Pantograph type 1,950**					
	Existing span length[1]	e_{use}	span length[3]	e_{use}	span length[4]	Difference
–	–	$D'_0 = I'_0 = 0{,}066$	–	$D'_0 = I'_0 = 0{,}000$	–	–
5,00	80,0	0,571	80,0	0,616	84,5	4,5
5,86 (5,50[2])	**80,0**	0,525	**74,0**	0,579	**80,5**	**6,5**
6,50	80,0	0,491	68,5	0,550	76,0	7,5

The parameter are used according to Table 1 [12], randomly related displacements according to Table 3 [12] (not fixed track), without constraints, overhead contact line system Re200 (see Figure 1), wind velocity 26 m/s, provisional value 0,03 m.

[1] usable span length in Germany up to publishing TSI ENE: 2014,
[2] nominal contact wire height for overhead contact line system Re200 in Germany additional the uplift,
[3] span length according to calculation procedure TSI ENE considering with reference cant 0,066 m,
[4] span length according to calculation procedure TSI ENE considering without reference cant 0,000 m.

contact line, leading to contact interruptions and to increased contact wire wear.

In 1961 German Railways (DB) reduced the maximum longitudinal span to 75 m for fixed messenger wire and 80 m for flexibly (auto) tensioned messenger wires without reference to a specific wind velocity [6]. Until now, 80 m long spans have been able to be used for standard overhead contact lines of German Railways (DB) for wind velocities up to 26 m/s. From the many electrified lines with longitudinal spans of 80 m and 5,5 m contact wire height no faults have been recorded, which could be considered as being caused by exceeding permitted wire displacements under wind. The reliable operation has confirmed the specified assumptions.

3. Flexibility

Flexibility s is a characteristic data of rail vehicles and expresses the relationship between the inclination angle η, which the body of a vehicle standing on a canted track forms with the perpendicular to the running plane due to the suspension, and the angle δ, which is formed by the running plane of the canted track and a horizontal line.

Predominantly, passenger cars have softer suspension than freight wagons or locomotives, whereby a softer suspension in curves with cant or cant deficiency leads to a higher displacement due to quasi-static effects and, therefore, to a wider infrastructure gauge. The testing of European railway lines and vehicles demonstrated, that the flexibility may assume values up to 0,375 [7, 11]. However, at that time modern vehicles often had higher flexibility with values up to 0,4. Therefore, the UIC working group 57A decided, to use this value as an assumed typical value for a reference vehicle [7].

The displacements due to quasi-static effects of vehicles with pantographs should be less than those for vehicles without pantographs on the roof, since the contact wire needs to be within the useable range of the pantograph. The development and design of a pantograph, however, depends on the displacement of the vehicle roofs, on which the pantographs are installed. The UIC working group, therefore, limited the flexibility to 0,225 for vehicles with pantographs on the roof [11]. Since then, this value has formed the basis for a reference value for the calculation of the vehicle gauge, the reference gauge and the infrastructure gauge. Higher values than 0,225 need to be excluded, as the larger vehicle movement could cause a de-wirement of the contact wire from the pantograph.

The assumed typical values of 0,4 for the flexibility of vehicles without pantographs on the roof and 0,225 for vehicles with pantographs on their roofs are based on experience from performance of traction vehicles existing at that time. Then, no vehicles existed with pantographs with flexibilities values of more than 0,225. No mathematical correlation between the flexibility 0,225 and the reference cant 0,066 m exists.

4. Reference data for cant u_0 and cant deficiencyu_{f0}

According to the TSI [13] the assumed typical values for reference cant u_0 and reference cant deficiency u_{f0} are 0,050 m to determine the lower part of the reference gauge and 0,066 m to determine the reference gauge for the pantograph and the equipment components mounted on the vehicle roof. The responsible working groups 57A and 57H of the *International Union of Railways UIC,* chose these reference values for the calculation of the vehicle and pantograph gauges in the 1950's.

These assumed typical values followed from consideration of the most unfavorable structural conditions on international railway main lines. Thus the St. Gotthard Crest Tunnel with only 3,34 m track spacing in straight line sections was considered decisive (Figure 2) [9]. Resulting from this track spacing and additional reserves of 0,025 m the width of the kinematic reference gauge was limited to 3,29 m (Figure 3). Since the most unfavorable position of the vehicle within the track and the axle and bogie play were assumed as fixed typical values, only the lateral displacements due to quasi-static effects resulting from the cant or a cant deficiency could be a selected variable. For the determination of a 3,29 m wide reference gauge, therefore, 0,050 m needed to be applied as reference cant and as reference cant deficiency.

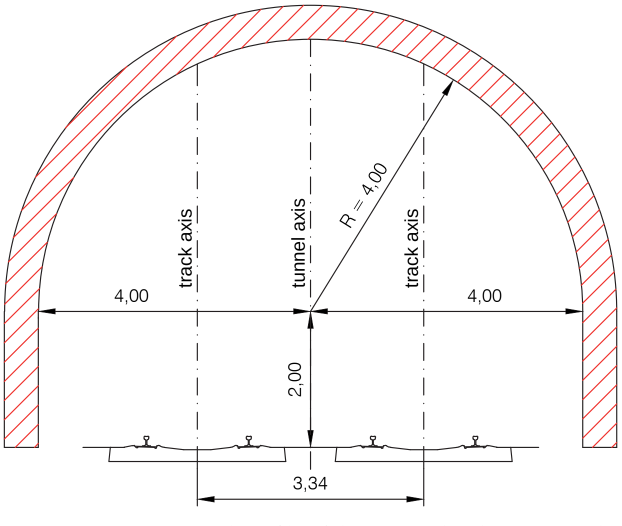

Fig. 2. Cross-sectional profile of the St. Gotthard crest tunnel (dimensions in m)

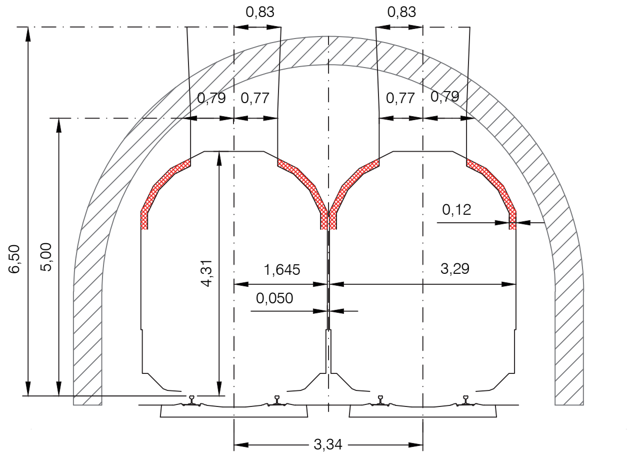

Fig. 3. Cross-sectional profile of the St. Gotthard crest tunnel with reference gauges (dimensions in m)

In the comments to UIC 505, unfortunately, no reason is given for the assumed typical value 0,066 m for determining the reference gauge of the pantograph. The origin, therefore, can only be supposed: Since the St. Gotthard Crest Tunnel formed the most unfavorable structural condition for the assumed typical value 0,050 m, it can be assumed that the assumed typical value 0,066 m followed from the St. Gotthard Crest Tunnel as well.

The transverse profile of the St. Gotthard Crest Tunnel is shown in Figure 2 [8]. On the basis of this cross section a distance of 0,79 m is obtained between the tunnel wall and the track axis at a height of 5,0 m. Considering analogously an additional reserve of 0,025 m the dimension 0,77 m is obtained for the reference gauge. From this value, firstly 0,660 m is deduced for half of the length of the pantograph bow (pan), which was approved for operation within the SBB network, and additionally the reference values for the transverse play between the wheelset and the car body (bogie) as well as the displacements due to transverse overswing, position tolerance and asymmetry [12] (Figure 4).

Consequently, a space of 0,0445 m remains for the displacements due to quasi-static effects (see Figure 4, value marked in red). When assuming a flexibility 0,225 the reference cant and the reference cant deficiency are calculated to be 0,066 m:

$$I'_0 = D'_0 = \frac{z' \cdot L}{s'_0 \cdot \left(h_u - h'_{c0}\right)} = \frac{0{,}0445 \cdot 1{,}5}{0{,}225 \cdot \left(5 - 0{,}5\right)} = 0{,}066\ \text{m}, \qquad (1)$$

where

z' – displacement due to quasi-static flexibility of the vehicle considered by the manager responsible for the vehicles,

s'_0 – flexibility for the pantograph gauge,

L – distance between rail centres of a track,

I'_0 – reference cant deficiency,

D'_0 – reference cant,

h'_{c0} – height of rolling centre above top of rail.

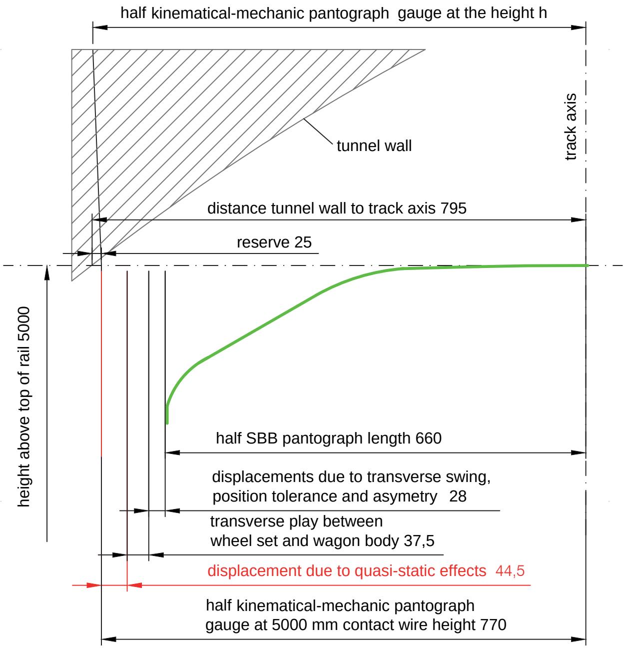

Fig. 4. Chain of dimensions to determine the displacements due to quasi-static effects (dimensions in mm)

The verification of the required minimum electrical clearances could be carried out as well (Figure 4). For this purpose the envelops of the 1320 mm pantograph according to UIC 608: 1971 [13] and an electrical clearance of 120 mm according to UIC 505-1 [13] were considered (Figure 5, value marked in red).

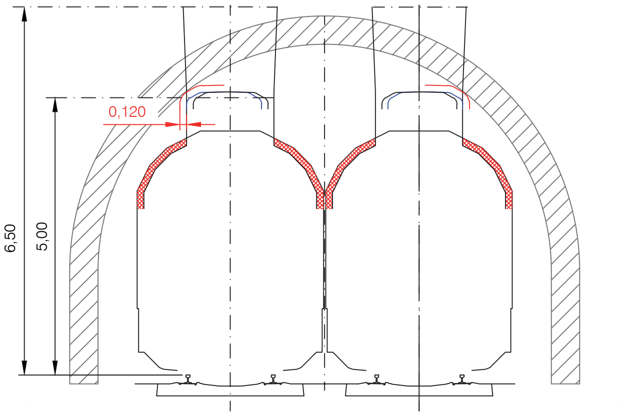

Fig. 5. Cross-sectional profile of the St.-Gotthard crest tunnel with reference gauges and the mechanical kinematic pantograph gauge (dimensions in m)

The assumed typical values for cant and cant deficiency do not result, from the real total movement of the vehicles but are only relevant for the definition of the reference gauge. The reference gauge is deduced from the most unfavorable structural conditions within the St. Gotthard Crest Tunnel. However, when calculating the useable contact wire lateral position the total movement of the vehicle is relevant. Therefore, I'_0 and D'_0 need to be selected equal to 0 m and the real existing cant and cant deficiency shall be used.

UIC 606-1: 1987 [18], as standard for approval of contact wire positions under wind actions, considers neither a cant nor a cant deficiency of 0,066 m when calculating the sufficient pantograph projection to verify that permitted wind displacement will not be exceeded and from which the working length of the pantograph head (pan) can be evaluated by subtracting the lateral sway of the pantograph head.

5. Recommendations for further development of TSI ENE

Since the initial application of flexibility, the reference values and their correlation have been explained and could be deduced from the tunnel profile and the track spacing within the special case of the St. Gotthard Crest Tunnel. The reference values $I'_0 = D'_0 = 0{,}066$ m in connection with a flexibility of 0,225 can be used for the calculation of the vehicle gauge, reference gauge and structure gauge, however, not for the calculation of useable contact wire lateral position. As a consequence, it is possible to assume the reference values $I'_0 = D'_0 = 0{,}0$ m in straight line sections and assume only the locally existing cant or the cant deficiency for calculations according to the TSI Energy. Then a calculation method can be obtained from the TSI ENE, which will be in line with the design data used and proven to date and resulting in the same useable contact wire lateral positions and longitudinal spans. Then, the new calculation methods of the TSI ENE: 2014 and positive long- term operational experience will be in agreement [10].

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TSI Energia 2015 – parametry referencyjne dla sieci trakcyjnej

Streszczenie
Użytkowany obszar poprzecznego położenia przewodu jezdnego, określony zgodnie z TSI ENE 2015 i EN 15273, na podstawie przesunięć pantografu względem osi toru, może być może być zmniejszony t o 16%. Zredukowanie tego obszaru skutkuje skutkuje krótszą nawet o 8 m rozpiętością typowych przewodów jezdnych użytkowanych w DB, a tym samym zwiększeniem kosztów inwestycji. Powodem są parametry odniesienia w stosunku do poprzecznego przesunięcia pojazdu ustanowione dla określenia skrajni infrastruktury, także dla nachylenia pojazdu na prostym torze w celu zapewnienia stabilności. Zakresy referencyjne uzyskano doświadczalnie w warunkach istniejącej infrastruktury kolejowej. Jednakże dla nowych instalacji te warunki nie są niezbędne. Specyfikacja TSI Energia 2015 powinna być poprawiona tak, aby przewody jezdne sprawdzone w długim okresie mogły być także używane w przyszłości.

Słowa kluczowe: sieć trakcyjna, interoperacyjność, techniczna specyfikacja dla zapewnienia interoperacyjności w podsystemie energetycznym, koleje konwencjonalne, koleje dużych prędkości, mechaniczna skrajnia kinematyczna pantografu, elektryczna skrajnia kinetyczna pantografu

Техническая спецификация TSI Energy 2015 – относительные параметры для контактной сети

Резюме
Используемое поперечное положение контактного провода, определенное согласно TSI ENE 2015 и EN 15273 опирающееся на передвижении пантографа по отношеню к оси пути, может уменьшиться на 16 %. Результатом уменьшения поперечного положения является пролет для типичных контактных проводов используемых в DB даже на 8 м короче и увеличение расходов. Причиной являются относительные параметры для поперечного передвижения единицы подвижного состава установлены для определения габарита инфраструктуры, также для наклона единицы подвижного состава на прямом участке пути для сохранения его устойчивости. Контрольные параметры были получены эмпирически в условиях существующей железнодорожной инфраструктуры. Однако для новых инсталяций эти условия не нужны. Спецификация TSI Energy 2015 должна быть прокоректирована таким образом, чтобы контактные провода проверенные в долгосрочной перспективе могли быть использованы в будущем.

Ключевые слова: контактная сеть, интероперабельность, техническая спецификация для интероперабельности, энергоэлектрическая подсистема, традиционная железная дорога, высокоскоростная железная дорога, механическая кинематическая контурная линия пантографа, электрическая кинематическая контурная линия пантографа