

UIC Code

796

O

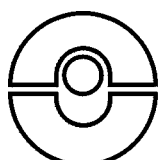
1st edition, April 2000

Translation

Voltage at the Pantograph

Tension au pantographe

Spannung am Stromabnehmer



*Union Internationale des Chemins de fer
Internationaler Eisenbahnverband
International Union of Railways*

UIC



Leaflet to be classified in Section :

VII - Way and Works

Application :

With effect from 1st July 1999

All members of the International Union of Railways

The person responsible for this leaflet is named in the UIC Code



Warning

No part of this publication may be copied, reproduced or distributed by any means whatsoever, including electronic, except for private and individual use, without the express permission of the International Union of Railways (UIC). The same applies for translation, adaptation or transformation, arrangement or reproduction by any method or procedure whatsoever. The sole exceptions - noting the author's name and the source - are "analyses and brief quotations justified by the critical, argumentative, educational, scientific or informative nature of the publication into which they are incorporated"

(Articles L 122-4 and L122-5 of the French Intellectual Property Code).

© International Union of Railways (UIC) - Paris, April 2000

Printed by the International Union of Railways (UIC)

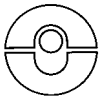
16, rue Jean Rey 75015 Paris - France, April 2000

Dépôt Légal April 2000

ISBN 2-7461-2-7461-0147-5 (French version)

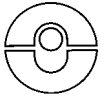
ISBN 2-7461-2-7461-0148-3 (German version)

ISBN 2-7461-2-7461-0146-7 (English version)



Contents

SUMMARY	1
1 - Scope	2
2 - Objectives	3
3 - Mean useful voltage at the pantograph: mean useful U.....	4
4 - Dimensioning train.....	6
5 - Voltage values	7
5.1 - Relation between mean useful U and $U_{min 1}$	7
5.2 - Values recommended for mean useful U at the pantograph	7
6 - Measurement and control on tractive unit.....	8
6.1 - General.....	8
6.2 - Data acquisition	8
6.3 - Analysis	8
6.4 - Comparison with the simulation.....	9
Appendix A - Selection criteria determining voltage at the pantograph for high speed trains	10
BIBLIOGRAPHY	12

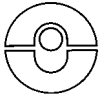


Summary

This leaflet briefly refers to generic documents concerning values for voltage at the OHL and voltage tolerances and then defines an index of the quality of voltage at (the) pantograph(s) (for categories of high speed line).

When dimensioning studies for electric traction fixed installations are carried out, mainly on the basis of simulated traffic, this index called the "mean useful voltage at train pantographs" is calculated using a formula which can be adapted to dedicated software. It reflects the level of performance that electric traction fixed installations can provide to different trains running in a given zone. Compliance with the minimum values indicated in the leaflet will enable infrastructure managers to guarantee a realistic simulation of the traffic graph.

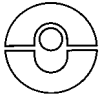
Lastly, the leaflet contains a method to verify that simulation results converge with measurements on board trains.



1 - Scope

This leaflet covers both:

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

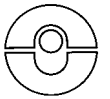


2 - Objectives

Within the scope of *UIC Leaflet 600* and the more general framework of *CENELEC standard EN 50163*, the aim of this leaflet is to define a mean useful voltage at train pantographs.

The idea is to obtain an indication of quality which cannot be measured physically and to use this in the simulations relating to the dimensioning and thus the definition of fixed installations for electric traction. It is founded on a mathematical study of voltage based on the power absorbed by trains.

NB : With the aim of guaranteeing for all trains the performance levels set out in the leaflet on line categories, the infrastructure manager should dimension his equipment in such a way that the mean useful voltage at the pantograph on each train in the zone is sufficiently high. This does not mean that trains will not, for very short periods, be subjected to extreme voltages as defined in the standards listed below.



3 - Mean useful voltage at the pantograph: mean useful U

For an explanation of this concept, (see Appendix A - page 10).

The mean useful voltage at the pantograph is defined as follows:

$$U_{\text{mean useful}} = \frac{\sum_{i=1}^{n_{\text{train}}} \frac{1}{T_i} \int_0^{T_i} U_{\text{panto}_i} \times I_{\text{panto}_i} \times dt}{\sum_{i=1}^{n_{\text{train}}} \frac{1}{T_i} \int_0^{T_i} I_{\text{panto}_i} \times dt}$$

Where:

- T_i = Integration or study period on train No. i
- n_{train} = Number of trains considered in the simulation

For a.c. electrification:

- U_{panto_i} = Momentary rms voltage at fundamental frequency at the pantograph of train No. i
- I_{panto_i} = Momentary rms current at fundamental frequency passing through the pantograph of train No. i

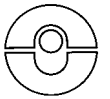
For d.c. electrification:

- U_{panto_i} = Momentary average d.c. voltage at the pantograph of train No. i
- I_{panto_i} = Momentary average d.c. current passing through the pantograph of train No. i

This represents the relationship 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 which is more suitable for some programs:

$$V_m = \frac{1}{MN\Delta t} \sum_{j=1}^N \sum_{k=1}^M V_{j, k}(t) \Delta t$$



Where:

n_{train}	=	number of trains considered in the simulation.
$V_{j,k}$	=	rms voltage of the fundamental calculated on the basic calculation step for a.c. electrification Average voltage calculated on the basic calculation step for d.c. electrification
M	=	number of calculation steps in the integration period.
N	=	number of integration periods over the simulation.
Δt	=	time during which each calculation step M is simulated

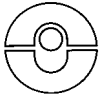
This voltage has the advantage that it reflects quite closely the quality of the power supply in the case of traffic simulations comprising a large number of trains on the railway under study.

The formulae above is used to study:

1. A geographic zone (i.e. the part of the network one wishes to study) in a given period of time, with account taken of all the trains passing through the zone, whether they are in traction mode or not (stationary, traction, coasting).

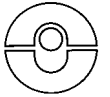
The value of mean useful U therefore acts as an indicator of the quality of the power supply for the entire zone.

2. The mean useful voltage at the pantograph of each train taken in isolation; only the traction periods of the train are taken into account.



4 - Dimensioning train

This is defined as the train with the lowest mean useful voltage. The study should concentrate on the power supply conditions of this train.



5 - Voltage values

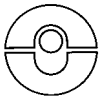
5.1 - Relation between mean useful U and U min 1

The dimensioning of the power supply should be conducted in such a way that the simulations enabling mean useful U at the pantograph to be computed never generate momentary voltage values at the pantograph of any train lower than the limit "U min 1" from *EN standard 50163* for traffic corresponding to the category of line concerned.

5.2 - Values recommended for mean useful U at the pantograph

The minimum values for mean useful voltage at the pantograph are given below:

Mean useful U at panto [kV]				
Electrification system in kV	1.5	3	15	25
Zone (<i>used for simulations</i>)	1.30	2.80	14.2	22.5
Uncoupled single train set (<i>used for simulations and verification</i>)	1.30	2.80	14.2	22.5



6 - Measurement and control on tractive unit

6.1 - General

The object of this point is to define the test methods for the verification of mean useful voltage at the pantograph of a tractive unit running on one of the lines under study; this being done within the context of traffic as listed in the table of line categories see *UIC Leaflet 795-0*.

The measurement shall be done on a critical or dimensioning train for the simulated service (see Point 4 - page 6).

Several measurements should be made on the same train, in order to verify the convergence of the results and their validity.

The reference timetable is the one used for the simulation.

NB : These measurements could for example be made on a day by day basis.

6.2 - Data acquisition

Voltage at the pantograph shall be measured so that the analysis described in point 6.3 (see page 8) is possible. Ideally the voltage should be recorded continuously or at least at the same interval used for the simulation (typically 5 seconds). Distance should be recorded at the same time so that the analysis called for in point 6.3 can be made.

If low-performance data acquisition chains are used, the distance between two measuring points shall not exceed 500 m, and the voltage shall be integrated over a minimum period of one second.

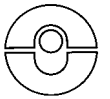
In the case of manual recording (where measurements are required immediately and there is not enough time to install measuring equipment), the voltage shown on the voltmeter shall be recorded at intervals of not more than 2,000 m.

6.3 - Analysis

From the recorded data, the following values or curves shall be calculated:

1. the curve of voltage against time,
2. the mean value V_m expressed as:

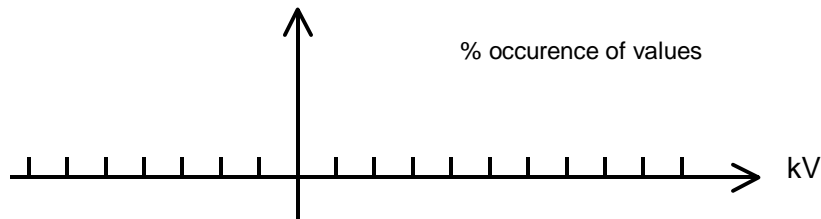
$$V_m = \frac{1}{MN\Delta t} \sum_{j=1}^N \sum_{k=1}^M V_{j,k}(t) \Delta t$$



Where:

- N = total number of periods measured
M = number of steps taken per measured period
 Δt = duration for which each of the M steps is measured

3. the statistical distribution curve shown below:



The steps to be used along the horizontal axis for the different power supply systems are as follows:

- 200 V step for 15 kV or 25 kV A.C
- 40 V step for 3 kV D.C
- 20 V step for 1.5 kV D.C

From this, standard deviation σ can be obtained.

6.4 - Comparison with the simulation

V_m is the only value that can be compared with the simulation result for mean useful voltage at the pantograph. This value must be higher than the one given in the table of point 5.2 (see page 7) of the present document.

It shall be verified that the recorded instant values of the voltage at the pantograph are not under $U_{min 1}$ (see Point 5.1 - page 7).



Appendix A - Selection criteria determining voltage at the pantograph for high speed trains

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

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

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, auto transformers e.g. 2 x 25 kV, and converters for d.c.) and compatibility with apparent performance tolerated at the HV connection points, the quality of the power supply constitutes an important qualifying parameter for the supply scheme studied.

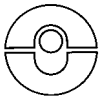
The characteristic curve of tractive effort/speed for a tractive unit changes as a function of the voltage at the pantograph. Determining the envelope of the characteristic tractive effort/speed curve, under reduced voltage is achieved in relation to the nominal characteristic curve, by extrapolation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

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, statistically not to drop below the minimum limit of 19 kV. Voltages below 19 kV are possible in periods of abnormal traffic with trains on closer headways in particular, or in the case of special situations that do not always appear in the simulations (coincidence of flights of traffic in directions 1 and 2).

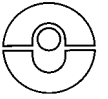
The incidence of situations with impaired performance, both from the point of view of the power supply scheme and the operating graph, should be assessed with account taken of permitted losses in performance.

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

- It allows the tractive 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 potential and that, as a result, increased traffic volumes can be considered.
- It allows certain impaired traffic situations to be dealt with.



Bibliography

CENELEC

"CENELEC standard EN 50163",