

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Railway applications – Rolling stock – Electrical equipment in trolley buses –
Safety requirements and current collection systems**

**Applications ferroviaires – Matériel roulant – Équipements électriques des
trolleybus – Exigences de sécurité et systèmes de captage de courants**



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**Applications ferroviaires – Matériel roulant – Équipements électriques des
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**Railway applications – Rolling stock – Electrical equipment in trolley buses –
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**Applications ferroviaires – Matériel roulant – Équipements électriques des
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CONTENTS

FOREWORD.....	5
1 Scope.....	7
2 Normative references	7
3 Terms and definitions	9
4 Voltages and classification of the voltage bands	12
4.1 Voltages	12
4.1.1 General	12
4.1.2 Operating voltages	12
4.1.3 Insulation voltages and test voltages	12
4.1.4 Overvoltages	13
4.2 Classification of the voltage bands.....	13
5 Trolley bus construction.....	13
5.1 Protection and electrical safety criteria	13
5.1.1 Protection criteria against direct and indirect contacts	13
5.1.2 Steps, stanchions, handrails, slopes and access platforms	16
5.1.3 Doors and door handles.....	16
5.1.4 Cabling	16
5.1.5 Open door interlocking.....	17
5.1.6 Leakage current detector	17
5.1.7 Intermediate mass insulation detector.....	17
5.1.8 Capacitors	18
5.1.9 Equipotential connections	18
5.1.10 Electromagnetic compatibility (EMC)	18
5.1.11 Overvoltage protection.....	19
5.2 Electrical components in band III voltage	19
5.2.1 General information	19
5.2.2 Current collection system	19
5.2.3 Electric traction equipment	20
5.2.4 Power supply independent from overhead contact line.....	21
5.2.5 Auxiliary groups	22
5.2.6 Heating and ventilation systems	22
5.2.7 Cables	22
5.3 Electrical components in band II voltage	23
5.3.1 General information	23
5.3.2 Cables	23
5.3.3 Separation from other voltage band circuits	23
5.4 Electrical components in band I voltage	23
5.4.1 General information	23
5.4.2 Cables	24
5.4.3 Separation from other voltage band circuits	24
6 Checks and tests	24
6.1 General information	24
6.2 New trolley-buses	25
6.2.1 Design and construction verification	25
6.2.2 Separate source applied voltage tests on circuits and components fed at voltages of the band III from the overhead contact line	25

6.2.3	Separate source applied voltage tests on circuits and components fed at voltages of the band III insulated from the overhead contact line	26
6.2.4	Separate source applied voltage tests on circuits and components fed at voltages of the band II	27
6.2.5	Tests of the insulation of entrance areas	28
6.2.6	Insulation resistance values for circuits and components supplied at band III voltages from the line voltage	28
6.2.7	Insulation resistance tests for circuits and components supplied at the line voltage	28
6.2.8	Insulation resistance values for circuits and components supplied at band III voltages insulated from the line voltage	29
6.2.9	Insulation resistance tests for circuits and components supplied at band III voltages insulated from the line voltage	30
6.2.10	Insulation resistance values for circuits and components supplied at a voltage of band II	30
6.2.11	Insulation resistance tests for circuits and components supplied at a voltage of band II	30
6.3	Overhauled trolley-bus	31
6.3.1	Tests and verification of the electrical equipment	31
6.3.2	Measurements and value of the insulation resistance	31
6.3.3	Insulation resistance tests	31
6.3.4	Trolley bus after minor or maintenance repairs	31
6.4	On-duty trolley-bus (periodic checks)	31
6.4.1	Insulation decay and provisions required	31
6.4.2	Periodical checks and tests of the insulation during maintenance	32
6.4.3	Periodical checks and tests of the insulation	32
6.5	Leakage detectors (overhaul, definitions, thresholds)	33
6.5.1	Operating voltages and temperature ranges	33
6.5.2	Operation and alarm of the detector	33
6.5.3	Limits and calibration of the detector	34
6.5.4	Periodic efficiency checks	40
Annex A (normative)	Constructional detailed provisions	44
A.1	General	44
A.2	Attachment of the current collection system and other components	44
A.3	Insulations	44
A.4	Ventilation	45
A.5	Accessibility	45
A.6	Location of the main circuit breaker	45
A.7	Inlet and outlet points of cables	45
A.8	Cabling	45
A.9	Test terminal board	45
A.10	Insulation leakage pre-alarm	45
A.11	Equipment connected to different voltage band circuits	46
A.12	Segregation of band III circuits	46
A.13	Batteries and other energy storage devices	46
A.14	Fuel cells	47
A.15	Environmental conditions	47
Annex B (informative)	Open door interlocking	48
Bibliography		49

Figure 1 – Insulation overview – Trolley buses	15
Figure 2 – Maximum displacement between vehicle centreline and catenary centreline	20
Figure 3 – Test circuits	27
Figure 4 – Megaohmmeter connection	29
Figure 5 – Megaohmmeter connection	30
Figure 6 – Leakage current monitoring	35
Figure 7 – Insulation resistance monitoring	36
Figure 8 – Touch voltage monitoring with sliding wires	37
Figure 9 – Touch voltage monitoring with grounded overhead contact line	38
Figure 10 – Compensation of the voltage drop on the grounded overhead contact line	39
Figure 11 – Voltage development with a load connected to the overhead contact line	40
Figure 12 – Function check of the leakage current monitoring	41
Figure 13 – Function check of the insulation resistance monitor	42
Figure 14 – Function check of the touch voltage monitor with vehicle mass (chassis)	43
Figure 15 – Function check of the touch voltage monitor with sliding wires	43
Table 1 – Nominal voltages and their permissible limits in values and duration	12
~~Table 2 – Insulation voltages and power frequency test voltages~~	~~13~~
Table 2 – Nominal voltages (U_N), rated impulse voltages (U_{Ni}) and short-duration power-frequency withstand voltage (U_a) for circuits connected to the contact line	13
Table 3 – Overvoltages	13
Table 4 – Voltages bands for trolley busses	13
Table 5 – Summary of electric tests	33

INTERNATIONAL ELECTROTECHNICAL COMMISSION

RAILWAY APPLICATIONS – ROLLING STOCK – ELECTRICAL EQUIPMENT IN TROLLEY BUSES – SAFETY REQUIREMENTS AND CURRENT COLLECTION SYSTEMS

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IEC 63076 edition 1.1 contains the first edition (2019-09) [documents 9/2530/FDIS and 9/2543/RVD] and its amendment 1 (2023-02) [documents 9/2736/CDV and 9/2807/RVC].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 63076 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

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This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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RAILWAY APPLICATIONS – ROLLING STOCK – ELECTRICAL EQUIPMENT IN TROLLEY BUSES – SAFETY REQUIREMENTS AND CURRENT COLLECTION SYSTEMS

1 Scope

This document applies to electrical systems aboard vehicles of the trolley bus type, as defined in 3.1, fed with a nominal line voltage (U_n) between 600 V DC and 750 V DC.

This document defines the requirements and constructional advice, especially to avoid electrical danger to the public and to staff. Where special requirements exist for trolley buses, advice is given for mechanical and functional safety, as well as for protection against fire.

This document covers vehicles intended for public transportation. This document applies to:

- trolley buses without on-board isolation interface from the contact line,
- buses with a current rail for guidance in the road surface,
- guided buses with bipolar roof current collectors.

This document does not apply to:

- a) electric driven vehicles fitted only with an internal power supply:
 - 1) hybrid vehicles,
 - 2) diesel-electric vehicles,
 - 3) fuel-cell vehicles,
 - 4) battery-powered vehicles,
- b) vehicles with safe protective bonding:
 - 1) rubber-tyred commuter trains,
 - 2) guided buses with power supplied by a separate current rail,
 - 3) rail-guided buses with unipolar roof current collector,
- c) vehicles operated outside publicly accessible areas:
 - 1) electrically driven lorries on motorways.

Guidance and current rails are special solutions and, at this time, are not subject to standardization, unlike trolley bus current collectors and overhead contact lines.

This document refers mainly to earthed networks, but reference is made also to galvanically insulated networks.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60077 (all parts), *Railway applications – Electric equipment for rolling stock*

IEC 60077-1, *Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules*

IEC 60322, *Railway applications – Electric equipment for rolling stock – Rules for power resistors of open construction*

IEC 60349 (all parts), *Electric traction – Rotating electrical machines for rail and road vehicles*

IEC 60479 (all parts), *Effects of current on human beings and livestock*

IEC 60479-1, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC 60479-2, *Effects of current on human beings and livestock – Part 2: Special aspects*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60571, *Railway applications – Electronic equipment used on rolling stock*

IEC 60721-3-5, *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities – Section 5: Ground vehicle installations*

IEC 60850, *Railway applications – Supply voltages of traction systems*

IEC 61111, *Live working – Electrical insulating matting*

IEC 61133:2016, *Railway applications – Rolling stock – Testing of rolling stock on completion of construction and before entry into service*

IEC 61287-1, *Railway applications – Power converters installed on board rolling stock – Part 1: Characteristics and test methods*

IEC 61373, *Railway applications – Rolling stock equipment – Shock and vibration tests*

IEC 61557-2, *Electrical safety in low voltage distribution systems up to 1 000V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 2: Insulation resistance*

IEC 61557-8, *Electrical safety in low voltage distribution systems up to 1 000 V a.c. and 1 500 V d.c. – Equipment for testing, measuring or monitoring of protective measures – Part 8: Insulation monitoring devices for IT systems*

IEC 61851 (all parts), *Electric vehicle conductive charging system*

IEC 61881 (all parts), *Railway applications – Rolling stock equipment – Capacitors for power electronics*

IEC 61991, *Railway applications – Rolling stock – Protective provisions against electrical hazards*

IEC 62128-1, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

IEC 62196-1, *Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 1: General requirements*

IEC 62236 (all parts), *Railway applications – Electromagnetic compatibility*

IEC 62497-1:2010, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*
IEC 62497-1:2010/AMD1:2013

IEC 62498-1, *Railway applications – Environmental conditions for equipment – Part 1: Equipment on board rolling stock*

IEC TS 62597, *Measurement procedures of magnetic field levels generated by electronic and electrical apparatus in the railway environment with respect to human exposure*

IEC 62928, *Railway applications – Rolling stock – Onboard lithium-ion traction batteries*

IEC 62995, *Railway applications – Rolling stock – Rules for installation of cabling*

ISO 6469-3, *Electrically propelled road vehicles – Safety specifications – Part 3: Electrical safety*

ISO 16750-2, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 2: Electrical loads*

ISO 16750-3, *Road vehicles – Environmental conditions and testing for electrical and electronic equipment – Part 3: Mechanical loads*

ISO 23273, *Fuel cell road vehicles – Safety specifications – Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

trolley bus

vehicle with rubber tyres (with limited lateral operating range or guided) without safe protective bonding of the chassis, which operates with an electrical drive in the public area accessible to persons and galvanically powered by an external supply line (overhead contact line, current rail)

Note 1 to entry: The two poles of the supply line are either both galvanically insulated from earth or one insulated and the other earthed. This can take place at a central point or at every feed (substation).

3.2

current-collection system

whole of the components, generally mounted on the vehicle's roof, having the task of taking the current from the overhead contact lines to supply the equipment of the vehicle, both in standing and in running conditions

3.3

mass

<for trolley bus> conductive part of an electrical component that is accessible and that is not energized in normal conditions, but can become energized in fault conditions

Note 1 to entry: The equipment defined in 5.4.1 as normal bus vehicle components are not included in this term.

Note 2 to entry: The conductive parts of the chassis and of the bodywork are defined as the vehicle mass.

3.4

intermediate mass

conductive part between two insulating parts of double-insulated equipment (protection, enclosure, etc.), which shall not be accessible to the public

3.5

basic insulation

<for trolley bus> insulation for personal safety, between the electric parts that are subject to energization and the intermediate mass, to provide basic protection against electric shock

3.6

supplementary insulation

<for trolley bus> insulation for personal safety between the intermediate mass and the vehicle mass

3.7

double insulation

insulation comprising both basic insulation and supplementary insulation

[SOURCE: IEC 60050-195:1998, 195-06-08]

3.8

functional insulation

<for trolley bus> insulation not for personal safety, with lower requirements, that ensures the function of the vehicle

Note 1 to entry: To some extent, the design is specified in the product standards.

3.9

nominal voltage

U_n

<for railways> designated value for a system to which the general characteristics are referred

3.10

rated voltage range

U_{Ne}

<for trolley bus> voltage range that, together with rated current, defines the use of the equipment and to which the applicable tests and the utilization categories are referred

3.11

highest permanent voltage

U_{max1}

maximum value of the voltage likely to be present indefinitely

[SOURCE: IEC 60850:2014, 3.4]

3.12

rated insulation voltage

U_{Nm}

<for trolley bus> value to which the dielectric test voltages and the creepage distances are referred and which cannot, in any case, be lower than U_{Ne}

Note 1 to entry: When no value is defined by the purchaser for U_{Nm} , the highest permanent voltage U_{max1} given by IEC 60850 is due to be assumed.

3.13

power-frequency test voltage

U_a

RMS value of sinusoidal power-frequency voltage that the insulation of the given equipment can withstand during tests made under specified conditions and for a specified duration

[SOURCE: IEC 60050-614:2016, 614-03-22]

3.14

highest non-permanent voltage

$U_{\max 2}$

maximum value of the voltage likely to be present for a limited period of time

[SOURCE: IEC 60850:2014, 3.5]

3.15

overvoltage

<for railways> any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions

[SOURCE: IEC 60850:2014, 3.6]

3.16

long-term overvoltage

overvoltage higher than $U_{\max 2}$, lasting typically for more than 20 ms, due to low-impedance phenomena, for example a rise in substation primary voltage

[SOURCE: IEC 60850:2014, 3.7, modified – Note1 to entry has been removed.]

3.17

highest long-term overvoltage

$U_{\max 3}$

voltage defined as the highest value of the long-term overvoltage for $t = 20$ ms

[SOURCE: IEC 60850:2014, 3.8, modified – The second sentence has been removed.]

3.18

dewirement

sudden and permanent detachment of one or both poles of the trolley from the overhead contact line(s) while the trolley bus is running

3.19

overhead contact line

catenary

contact line that is placed above or beside the upper limit of the vehicle's clearance, which supplies traction units with electrical energy via roof-mounted current collection equipment

Note 1 to entry: The characteristics of the overhead contact line are to be made known to the manufacturer, together with the type of service, the environmental conditions and the road profile. Mechanical properties are given in IEC 60913, minimum heights are given in IEC 62128-1.

[SOURCE: IEC 60050-811:2017, 811-33-02 – modified – Note 1 to entry has been added]

3.20 rated impulse voltage

U_{Ni}
impulse voltage value assigned by the manufacturer to the equipment or a part of it, characterising the specified withstand capability of its insulation against transient overvoltages

Note 1 to entry: U_{Ni} is higher than or equal to the working peak voltage.

[SOURCE: IEC 62497-1:2010, 3.4.7]

4 Voltages and classification of the voltage bands

4.1 Voltages

4.1.1 General

The voltage definitions used in this document are those of IEC 60850 and IEC 62497-1, where the following applies to direct voltage networks in compliance with IEC 60850.

4.1.2 Operating voltages

The equipment shall operate at the voltages, for overhead contact line systems, specified in Table 1.

Table 1 – Nominal voltages and their permissible limits in values and duration

Nominal voltage U_n V DC	Rated voltage range U_{Ne} V DC	Highest permanent voltage U_{max1} V DC	Highest non-permanent voltage U_{max2} V DC
600	400 to 720	720	800
750	500 to 900	900	1 000

NOTE In France, Belgium and the United Kingdom, different national regulations (IEC 60850) apply, which, however, do not apply to trolley buses.

For vehicle wash plants, in accordance with IEC 62128-1, the maximum allowed voltage is 120 V DC (voltage band II). In this case, the vehicle washing plant is not part of the workshop where the maximum allowed voltage is 60 V DC (voltage band I).

4.1.3 Insulation voltages and test voltages

Insulation in accordance with IEC 62497-1 shall be designed and tested with reference to the following voltages shown in Table 2.

Table 2 – Insulation voltages and power frequency test voltages

Nominal voltage U_n V DC	Rated insulation voltage U_{Nm} V DC	Power frequency test voltage U_a V DC
600	≥ 720	refer to IEC 62497-1:2010, Table B.1
750	≥ 900	

Table 2 – Nominal voltages (U_n), rated impulse voltages (U_{Ni}) and short-duration power-frequency withstand voltage (U_a) for circuits connected to the contact line

Nominal voltage U_n V DC	Rated insulation voltage U_{Nm} V DC	Rated impulse voltage U_{Ni} V DC	Power frequency test voltage U_a V DC
600	720	See IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table A.2	See IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table B.1
750	≥ 900		

4.1.4 Overvoltages

The equipment shall withstand the overvoltages of the overhead contact line system specified in Table 3.

Table 3 – Overvoltages

Nominal voltage U_n V DC	Highest long-term overvoltage U_{max3} V DC
600	1 270
750	1 270

4.2 Classification of the voltage bands

In accordance with IEC 61991, the voltage bands applicable to trolley buses are in accordance with Table 4.

Table 4 – Voltages bands for trolley busses

Band	Nominal voltage V	
	AC	DC
I	$U_n \leq 25$	$U_n \leq 60$
II	$25 < U_n \leq 50$	$60 < U_n \leq 120$
III	$50 < U_n \leq 1\,000$	$120 < U_n \leq 1\,500$

5 Trolley bus construction

5.1 Protection and electrical safety criteria

5.1.1 Protection criteria against direct and indirect contacts

The best criteria and arrangements shall be adopted in the design and in the manufacture of trolley buses to avoid, or at least minimize to a non-dangerous level, all touch voltages and, in particular, the voltage differential between mass and earth potentials and to detect leakages before the associated voltages reach a dangerous level.

Limit values for touch voltages are specified in IEC 62128-1. Limit values for shock currents are specified in the IEC 60479 series.

NOTE Different limit values for touch voltages apply in Switzerland (SR 734.2).

The requirements of IEC 61991 shall apply wherever applicable.

Since the highest hazard potential is present when touching the outside of the vehicle, the requirements of IEC 61991 of a verifiable double insulation are supplemented by a third insulation in the area of the doors, where passengers would be most likely to come into contact with voltages.

If possible, the double insulation shall be designed such that a fault cannot bridge both paths at the same time.

Layout of insulation distances depending on material and degree of pollution shall be carried out in accordance with IEC 62497-1.

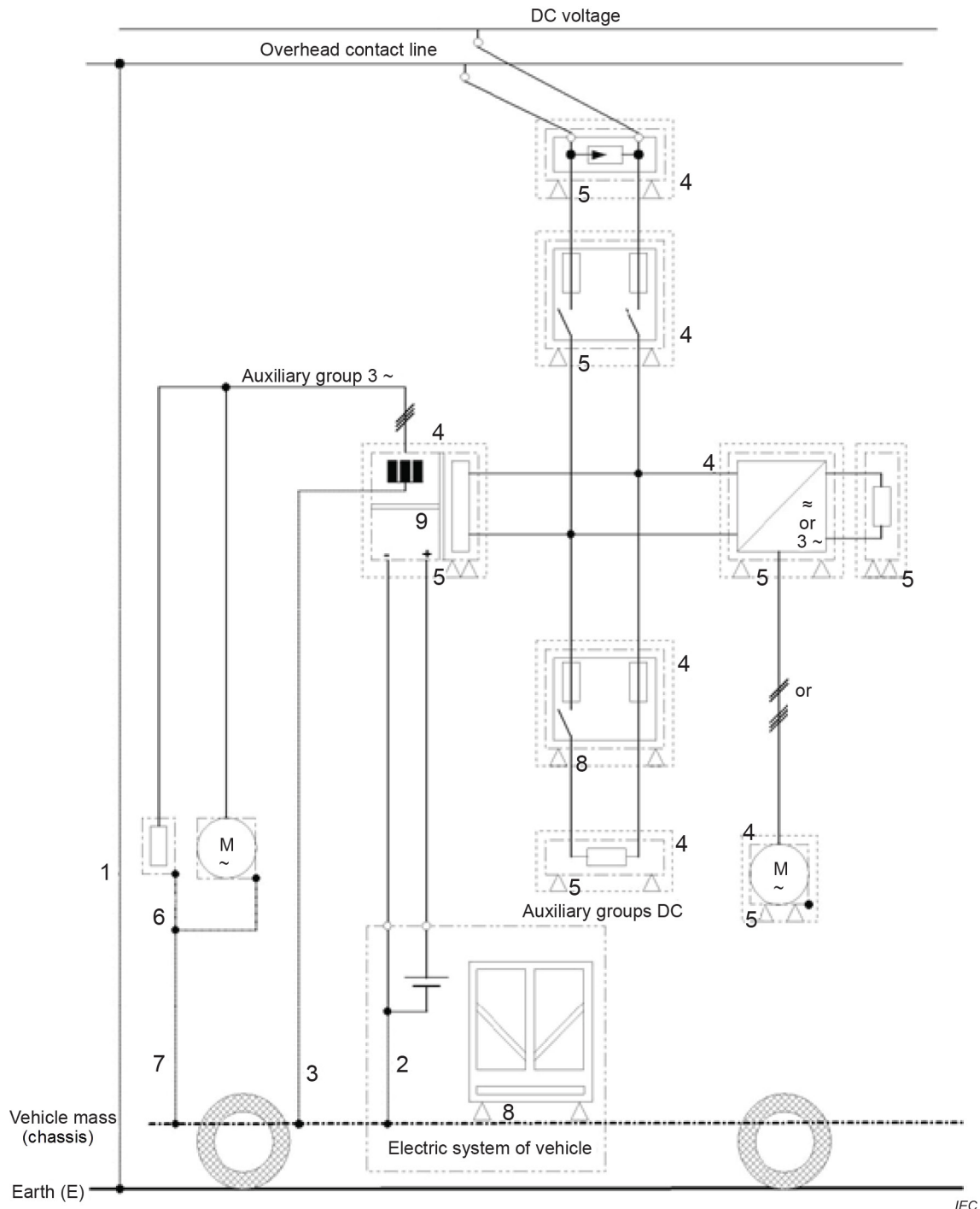
Always make sure, for external insulation, that part of the insulation remains protected from moisture or dirt. If this is not possible, greater distances and/or other materials shall be selected because of the higher minimum insulation resistances in systems with no protective bonding (see Table 6).

Figure 1 provides an overview of the double insulation requested for this vehicle type in IEC 61991 as well as of the third insulation of the doors.

The expansion of the basic insulation to double insulation always applies to all three types of interfaces of the component:

- supplementary insulation of the mechanical mounting;
- supplementary insulation of the power supply module;
- supplementary insulation of the signal interfaces.

The marking by warning signs of installation spaces containing circuits with voltages of bands II and III or power circuits of band I shall comply with IEC 61991.



Key

- 1 conducting connection of substation output to earth, if applicable
- 2 conducting connection of DC onboard power supply to vehicle mass (chassis), if applicable
- 3 conducting connection between the neutral point of the transformer of the static converter and vehicle mass (chassis) as protective conductor, if applicable (see also 7)
- 4 protection of direct contact of all intermediate masses (enclosure, roof insulation, underfloor installation)
- 5 supplementary insulation for implementation of the double insulation. Basic or functional insulation are represented by enclosures, double insulation of cables is not depicted
- 6 conducting connection of all enclosures of three-phase AC loads (protective bonding if applicable)
- 7 conducting connection of all enclosures of three-phase AC loads and vehicle mass (chassis) as protective conductor (see also 3)
- 8 supplementary insulation of entrance areas (doors, access platforms, push buttons) if applicable
- 9 double insulation inside devices (depicted only for static converter)

Figure 1 – Insulation overview – Trolley buses

The insulation resistance of outside insulation as a factor of the atmospheric conditions and vehicles, which may have insulation defects, can fall short of the limit values for personal safety.

For this reason, measures specified in this subclause shall be taken independently of the overhead line network configuration (earthed or galvanically isolated).

5.1.2 Steps, stanchions, handrails, slopes and access platforms

To prevent persons entering or leaving the vehicle from sensations of discharge of the vehicle mass (chassis) exceeding the threshold of perception, entrance areas shall be equipped with insulating materials as protective impedances.

Steps, stanchions and handrails facing all doors shall be insulated from the vehicle mass (chassis) or made of insulating material. Slopes and access platforms for handicapped persons shall be insulated from the vehicle mass (chassis).

Entrance areas shall be designed with drip edges at the end of the base plate and with a drain for ingressed water. Direct contact of surface water with other parts of the vehicle mass (chassis) shall be prevented.

The function of protective impedance of entrance areas shall be ensured by regular cleaning of the entrance areas and visual inspection of material by qualified staff. Detergents shall be chosen to avoid chemical wear of the material.

During visual inspection, the material shall be closely examined for any damage that affects the dielectric properties, such as fractures, cracks or pinholes (6.2.5). The dielectric properties of the material shall comply with the requirements for basic insulation in 6.2.

A visual inspection of the cleaned entrance areas is required and is included in the periodic insulation test procedure in 6.4.

5.1.3 Doors and door handles

All doors and relevant accessories, except for control equipment not accessible to the public, shall be insulated from the vehicle mass (chassis) or made of insulating material.

To provide sufficient creepage distances, plastic door handles or outside sliding doors without handles are recommended.

5.1.4 Cabling

Conduits of cables fed at voltages of band III shall be segregated from those containing cables fed at voltages of bands I and II; band III conduits and trunking shall be easily detectable by means of suitable markings.

In the case of double insulation conduits of band III, cables being part of different circuits shall be segregated according to IEC 62995.

Rescue workers in cities with trolley buses and overhead contact lines are specially trained, so special labelling in classic trolley buses with or without auxiliary power supplies with diesel engine generators is not required, because the whole system can be switched off. An exception is the cabling of energy storage devices, which shall be labelled orange up to the first circuit breaker¹.

¹ See ECE Regulation No. 100.

5.1.5 Open door interlocking

Traction equipment shall be provided with an interlock to prevent the vehicle from starting while the vehicle doors are open. This interlock device shall include a push button or a similar padlocked device enabling the driver to by-pass the feature.

5.1.6 Leakage current detector

It is recommended, upon agreement between the manufacturer and the operator and matched with the supply system, to equip trolley buses with an automatic measuring instrument, defined as a leakage detector. Appropriate information shall be provided by the operator.

The device generates an optical/acoustic alarm signal when the insulating resistance between the circuits fed at line voltage and the vehicle mass (chassis) falls below the permissible limit values. Depending on the type of measuring method, exceeding the permissible touch voltage or the permissible leakage current may also be used as the criterion. The permissible insulation resistance is calculated from the supply voltage in accordance with IEC 60850 and the threshold of feeling from the permissible shock current specified in the IEC 60479 series.

When the above-mentioned limit values have been reached, the device can open the line contactor and lower the trolley poles automatically when the vehicle is stationary, if this feature is possible and requested by the operator. The vehicle may feature a key switch or a similar sealable device that enables the driver to disable the function, if the operator requests this for emergency mode. If the vehicle has an auxiliary source of energy, it shall be used for the emergency mode.

Since the trolley poles are lowered actively and an opening of the line contactor alone cannot shut down the entire system, safety is implemented only by the protective measure "double insulation" supplemented by the insulation of the entrance areas.

The detection of an insulation resistance value below the permissible limit is considered to be part of preventative maintenance. As a result, this will increase the level of safety for passengers above the level that would have been achieved by interventions only at the mandatory intervals (see also Clause A.10).

The leakage detector or at least the relevant optical/acoustic alarm device, if any, shall be mounted at the driving position, in a location easily visible by the driver. An external display can be agreed between the operator and the manufacturer.

Where required and part of the equipment, the device may feature a means of self-diagnosis and shall meet the resulting safety criteria. In this case, the characteristic shall be accepted by an acknowledged authority.

Since the device itself shall feature a basic and a supplementary insulation because it is interconnected with the system to be monitored, it can cause insulation faults itself. This shall be taken into account, especially in the design. For this reason, the device shall be included in the dielectric tests with voltages in accordance with IEC 62497-1: 2010, Table B.1, as well as in the mandatory periodic test.

5.1.7 Intermediate mass insulation detector

Where a leakage detector is provided, a device suitable to detect the insulation level of the various intermediate masses to the relevant parts, connected to an overhead contact line or to the vehicle mass (chassis), can be installed for preventative maintenance upon agreement between the manufacturer and the operator. This device can be combined with the leakage detector specified in 5.1.6. The intermediate masses shall be electrically isolated from each other.

In exceptional cases and for justified constructional reasons, some intermediate masses for functionally homogeneous equipment may be connected with each other. In this case, the dielectric strength between the intermediate masses is particularly important.

The leakage detector of the vehicle's intermediate masses facilitates preventative maintenance and can thus increase the safety of the passengers.

5.1.8 Capacitors

For capacitors fed with voltages within band III, which may retain charge when they become accessible to direct contact during maintenance, means shall be provided to ensure that there is no risk of electric shock. This may be by means of integral design of discharge circuits, additional circuits or procedure. The implementation shall be agreed between the operator and the manufacturer.

To achieve the best safety conditions, steps shall be taken to prevent personnel from having unintentional access to parts with harmful voltages. In this context, the provisions of IEC 61991 and of the IEC 61881 series shall apply.

5.1.9 Equipotential connections

For insulated circuits of band III that are not directly fed from the contact wire, protective measures in compliance with IEC 61991 shall be taken.

In the case of articulated trolley buses or connected coaches, these elements of the vehicle shall be electrically interconnected, in order to have vehicle mass (chassis) at the same potential. These equipotential connections shall be easily found and suitably marked. For the identification of the connections and the equipotential bonding circuit, the requirements of IEC 62995 shall be applied.

5.1.10 Electromagnetic compatibility (EMC)

The on-board electrical and electronic equipment shall not cause or suffer in the vehicle and in the surrounding ambient interferences of electrical, magnetic or electromagnetic origin at such a level as to endanger the correct operation of the control, calibration, safety, radio-transmission devices etc., owing to emissions conducted, induced or radiated.

Field strength limits in the vehicle and in its vicinity shall not exceed the limit values of the relevant standards of individual countries.

NOTE In Europe EN 45502 series is applicable.

As a basis, the IEC 62236 series with emission values in compliance with IEC TS 62597 shall apply. For frequencies that were not taken into account in IEC TS 62597 with respect to human exposure, national practices or rules should be followed.

Interference suppression measures in parallel with individual insulation distances shall not exceed the limit values in accordance with IEC TS 60479-2 for switching processes, since these transients become significant in the case of an insulation fault of the supplementary insulation.

Intermediate masses that may feature alternating voltage potentials by capacitive coupling shall be wired such that the limit values in accordance with the IEC 60479 series are not exceeded. These potentials become significant in the case of an insulation fault of the supplementary insulation.

The operator shall also specify the critical frequencies of the existing infrastructure (to operate switches). Interference from other systems (e.g. traffic lights) shall be considered. If necessary, an EMC plan shall be drawn up and to be agreed between the manufacturer and the operator.

5.1.11 Overvoltage protection

To limit atmospheric overvoltages, surge arresters shall be provided in the supply system, which reduce the stress of basic and supplementary insulation. The implementation (at regular intervals on the overhead contact line, at the substations) and the data of the surge arresters shall be provided by the operator.

To limit overvoltages of the supply system, surge arresters shall be provided on the vehicle, which reduce the stress on the functional insulation. The data of the surge arresters shall be agreed between the vehicle manufacturer and the operator.

5.2 Electrical components in band III voltage

5.2.1 General information

The electrical components fed at a voltage of band III and connected to the overhead contact line shall be specifically made for electric traction, suitable for use in trolley bus services, with double insulation to the vehicle mass (chassis) and with both the pole terminals isolated from intermediate mass.

For the electrical and mechanical characteristics, the specific standards for the product apply.

5.2.2 Current collection system

Double insulation or reinforced insulation shall be applied between the live part and the vehicle mass (chassis) when the current-collection system is installed.

The insulator of the current collection system shall have a waterproof structure, and an anti-fouling smooth surface in order to increase the creepage distance and to ensure the insulation performance of the current collection system.

When the vehicle's speed is not less than 5 km/h, the longitudinal centreline of the vehicle can be shifted left or right to the centreline of the catenary with the maximum displacement of 4 500 mm (for a 6 200 mm trolley-pole system) or 4 000 mm (for a 5 500 mm trolley-pole system), as shown in Figure 2.

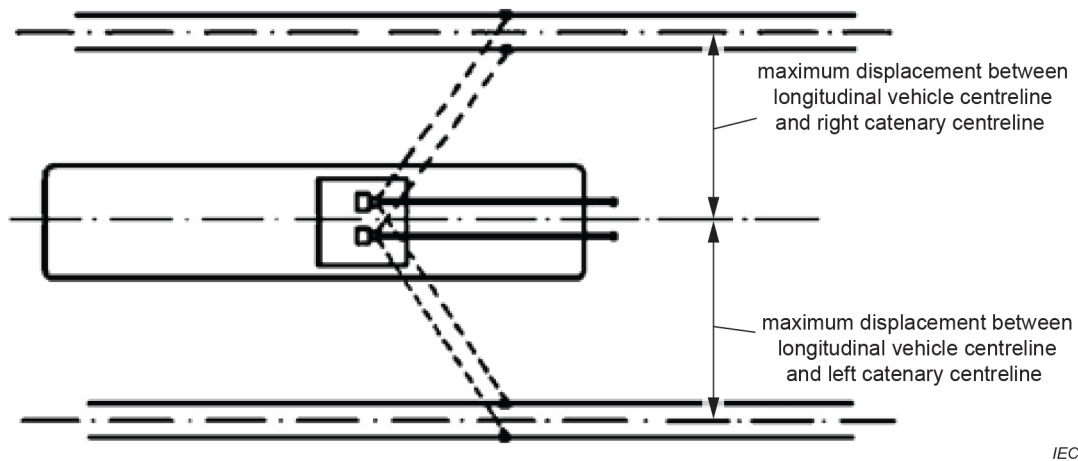


Figure 2 – Maximum displacement between vehicle centreline and catenary centreline

When the trolley poles are used as electrical connections, they shall be covered by insulation that is sufficient to allow functional insulation to prevent shorting of the overhead contact line in the event of dewirement.

The cables between the current collector head and the vehicle equipment shall be suitable for use on trolley buses and have specific electromechanical characteristics for this application, because of its mechanical and environmental stresses (cabling in accordance with IEC 62995). When the cable is arranged on the current-collection system, it cannot be applied by force, and cannot affect the activities of the current-collection system, and it is resistant to bending, moisture resistance, sunshine and easy aging.

Under the circumstances of the absence of supply voltage, the relevant electronic device failure and lack of air pressure, the trolley poles shall be lowered (for example, via rope) or at least a signal shall be indicated on the driver's desk.

5.2.3 Electric traction equipment

5.2.3.1 General information

The electric traction equipment mainly comprises the traction motor(s), the converter for motoring and braking, and the resistor (if fitted, for starting and/or braking).

The traction-control equipment is considered part of the traction equipment from a functional point of view.

5.2.3.2 Traction motors

For the traction motors, the requirements of the IEC 60349 series apply.

The motors shall be arranged to have a double insulation both in respect of the fixing to the vehicle mass (chassis) and of the connection to the transmission outputs, as well as other mechanical (cooling) and electrical interfaces (sensors).

5.2.3.3 Traction and braking

The requirements of IEC 61287-1 apply to the electronic power equipment.

The requirements of the IEC 60077 series apply to electromechanical drive.

The requirements of IEC 60571 apply to electronic control equipment.

The equipment shall be installed in body compartments or enclosures, suitably ventilated and accessible only to the personnel maintaining the trolley buses. All the live parts shall have double insulation with respect to the vehicle mass (chassis), except for those galvanically insulated from the line voltage, and shall be in any case protected from undue accidental contact when energized. They shall be safeguarded against accidental contact if live.

5.2.3.4 Starting and braking resistors, resistor for current-operated switches

The requirements of IEC 60322 apply to the electrical resistors. They shall be mounted so that the live parts have double insulation relative to the vehicle mass (chassis) and with suitable barriers or arrangements for protection from undue accidental contacts when energized.

The insulation between live components and the mechanical intermediate frame is only a functional insulation (primary insulation in accordance with IEC 60322). Thus, the double insulation requires another intermediate mass insulated from the vehicle mass (chassis) and the intermediate frame.

When the heat produced by the resistors is used for heating the driver and/or the passenger compartment, the relevant ducts, if made of conducting material, shall be electrically connected to the vehicle mass (chassis).

The active parts of the resistors as well as exterior insulators shall be protected by a suitable barrier against flying debris (e.g. leaves) to prevent fire and bridging of insulation distances.

5.2.4 Power supply independent from overhead contact line

5.2.4.1 General information

Trolley buses may be equipped with equipment for running with an auxiliary source of electrical energy, differing from the overhead contact line.

This equipment may be an electricity-generating thermal engine, a group of batteries or other equivalent means suitable to supply the traction motor(s).

Depending on the power of the independent power supply, one can differentiate between emergency power supply to clear the road, auxiliary power supply for restricted service or main power supply. Even if emergency power supplies limit the operation range to the overhead line grid, the thermal capacity of the endurance braking system is relevant for the homologation of the brake system².

As far as the control and safety systems are concerned, they can remain in use as in normal running.

5.2.4.2 Independent power supply and its insulation requirements

All electrical components for specific use for operation in independent running shall have the same characteristics as required for equipment fed at the same voltage band.

For operation on the overhead contact line, a facility for energy storage and recovery shall thus feature double insulation (see Clauses A.13 and A.14).

If every electrical connection between the overhead contact line and the electrical source for independent operation is explicitly broken without having to lower the trolley poles, double insulation is not required. In this case, a mechanical or electrical interlock of the switchgear

² See ECE Regulation No. 13.

that connects the system to the overhead contact line or the auxiliary power supply suffices. The open contacts of the contactors shall meet the requirements for basic or supplementary insulation, depending on the choice of basic and additional insulation for the independent power supply. Because the power connection of the energy source shall be regarded as an intermediate potential, an insulation check for the power connection shall be agreed between the manufacturer and the operator.

The equipment mentioned in 5.2.3.1 may be used for feeding the traction motor(s).

It shall be possible to disconnect the independent power supply from the system for maintenance purposes. This may be done by means of switches, fused circuit breakers or electromagnetic switchgear. With engine-driven auxiliary power supplies, it is sufficient to shut down the engine if it can be secured against restarting.

5.2.5 Auxiliary groups

The auxiliary groups fed at line voltage (e.g. the auxiliary motors for driving the compressor, the fans, the hydroguide pump, the auxiliary generators, and the static converters) shall have a double insulation with respect to the vehicle mass (chassis), independent from the overhead line network configuration (earthed or galvanically insulated).

The equipment supplied through circuits, which are galvanically singly insulated (basic or supplementary insulation) from the line may be mounted without insulation. The basic insulation of this equipment shall fulfil the requirements of basic or supplementary insulation, depending on its function as part of the double insulation.

The equipment supplied through circuits galvanically double insulated from the line may be mounted without insulation. Relevant for the basic insulation of this equipment is the rated voltage of the connected circuit. For the use of industrial devices (electronics, converters, motors), the corresponding industrial standards shall be applied.

NOTE The corresponding industrial standards are the IEC 60146 series, EN 50178 and the IEC 60034 series, etc.

Protective measures against electrical hazards shall be in compliance with IEC 61991.

5.2.6 Heating and ventilation systems

When space heaters or air conditioning equipment, for different uses, contain components supplied by band III voltages, the requirements given in 5.2.4 shall apply. Ventilation ducts, if made of conducting material, shall be connected to the vehicle mass (chassis).

In this case, the implementation of the devices and the airflow shall comply with national practices or rules for fire protections.

NOTE In Europe, EN 45545-5 is applicable.

5.2.7 Cables

The cables for the circuits at a voltage of band III shall be of the non-propagating flame type, with low emission of smoke and toxic or corrosive gases. They shall comply with IEC 62995 that is applicable to the use in trolley buses.

NOTE 1 In Europe, EN 50264 and EN 50306 series are applicable.

Connecting instructions of IEC 62995 shall be taken into consideration. Laying of cables shall comply with national practices or rules for fire protections.

NOTE 2 In Europe, EN 45545-5 is applicable for fire protections.

In particular, power cables in passenger compartments or ventilation ducts may only be laid in metal ducts. Cables that cannot be fused (e.g. upstream of the in-line fuse) shall feature double insulation.

5.3 Electrical components in band II voltage

5.3.1 General information

The electrical components supplied at a voltage of band II shall be two-pole and insulated from the vehicle mass (chassis). They shall be protected by means of fuses or automatic breakers having a suitable breaking capacity and they shall be suitable for use on trolley buses. When there is the need of having components on the vehicle fed at voltages pertaining to different bands, suitable arrangements shall be taken for an effective electrical segregation.

Protective provisions against electrical hazards shall be in accordance with IEC 61991 for insulated supply systems.

5.3.2 Cables

Refer to 5.2.7.

5.3.3 Separation from other voltage band circuits

The circuits related to the components given in 5.3.1, which are mounted on the same structures with cables for voltages of bands I and III, shall be designed for a suitably segregated installation. The connection points, if any, of cables for voltages in band II and apparatus at voltages in bands I and III, shall be carefully designed in respect to distance, mechanical protection and insulation between voltages.

Installation instructions of IEC 62995 shall be observed. An identification of the different voltage bands shall be agreed between the operator and the manufacturer.

5.4 Electrical components in band I voltage

5.4.1 General information

Protective measures against electrical hazards shall be in accordance with IEC 61991 for insulated supply systems.

The electrical components supplied in voltage band I are interconnected via additional signal lines and data buses, no distinction between trolley bus components (specifically for trolley buses) and normal bus components (automotive electrical) is made. Because part of the components has no insulated bipolar supply, withstand voltage and insulation resistance tests do not apply to approval.

Trolley bus components with single insulation from the overhead line voltage shall have a bipolar supply and shall be powered by an additional galvanically insulated supply employing the same basic or supplementary insulation as equipment connected to overhead contact lines. A test connection for the intermediate potential shall be agreed between the operator and the manufacturer.

IEC 61373 or ISO 16750-3 shall be used for shock and vibration tests, if applicable. Owing to the different mechanical loads of railways and rubber-tyred vehicles, the applicable category shall be agreed between the manufacturer and the operator for the use of IEC 61373.

If it is necessary to install, in the vehicle, electrical components fed by voltages of different voltage bands, an effective electrical separation shall be ensured.

5.4.2 Cables

Refer to 5.2.7.

5.4.3 Separation from other voltage band circuits

Refer to 5.3.3.

6 Checks and tests

6.1 General information

The requirements contained in this sub-clause concern the dielectric tests to be carried out specifically on trolley bus equipment. Test on components are specified in the relevant product standards and applied. Electrical tests, relevant for this document, are to be found in IEC 61133:2016 under:

- IEC 61133:2016, 8.7 Electrical insulation tests (routine tests);
- IEC 61133:2016, 8.7.1 General;

NOTE 1 Verification of double insulation, clearances and creepage distances in accordance with IEC 62497-1.

- IEC 61133:2016, 8.7.2 Voltage withstand test;

NOTE 2 In accordance with this document.

- IEC 61133:2016, 8.7.3 Insulation impedance test;

NOTE 3 Verification of insulation resistance and insulation monitoring in accordance with this document.

- IEC 61133:2016, 8.8 Protective bonding and return circuits tests (routine and safety-related test).

These tests may be conducted alternatively on the vehicle, the device or at a test bench. The testing equipment shall comply with IEC 61557-2.

Alternating voltage and direct voltage tests stress the fixed insulations more since voltage of this kind is applied for a much longer time compared to pulse voltage. Insulation may be damaged by the test. Product standards take this into account by permitting a shorter test period in the case of high AC test voltages or DC test voltages, in accordance with IEC 62497-1.

Thus, to be able to document the influence of the withstand voltage test on the insulation, it is recommended to perform the insulation resistance measurement in accordance with 4.2 before and after the withstand voltage test.

For the routine test, test voltage of the repeated dielectric test may be reduced to the initial test voltage in accordance with IEC 60077-1. Since the product standards consider the above annotation from IEC 62497-1, they shall be given preference for the routine tests to reduce the pre-damage of insulation sections. These deviations are explicitly pointed out in the following text in the relevant passages.

If applicable, the limit value of the leakage current for the individual tests should be specified and logged by the manufacturer.

Checking of the insulation should be carried out at least every three months. An alternative is an interval of 15 000 km of operation, which may be increased to 30 000 km on agreement with the operator, considering the limit firstly encountered between the two given above. These intervals can be prolonged if the pre-alarm device mentioned in Clause A.10 is present and the readings indicate frequent insulation checks are being made.

NOTE 4 In Italy, 2 months or 10 000 km apply because of legal prescriptions.

The limit values for the insulation for a new trolley bus, for an overhauled trolley bus and for a trolley bus during normal service are listed in 6.4.

6.2 New trolley-buses

6.2.1 Design and construction verification

The compliance of the vehicle to the requirements of Clause 5 shall be verified, particularly with respect to the insulation of the equipment having voltages in band III, especially those circuits with double insulation fed by the overhead contact line.

The design documents of the electrical part shall list and show the various intermediate masses, on which the electrical tests specified below shall be carried out.

The design documents of the mechanical part shall specify the dimensions of the clearances and creepage distances, and the properties of the insulation materials.

In accordance with IEC 62497-1, creepage distances can be checked by measurement only. Only insulation distances, implemented when mounted in the vehicle, need to be measured in compliance with IEC 61133:2016 and the impact caused by ageing, weather conditions, and deformation due to operation shall be taken into account. For the routine test in accordance with IEC 61133:2016, an additional visual inspection suffices.

6.2.2 Separate source applied voltage tests on circuits and components fed at voltages of the band III from the overhead contact line

Circuits and electrical components at the line voltage and those fed at voltages of the band III, with double insulation from the vehicle mass (chassis), shall be submitted to voltage tests, carried out on new material when the vehicle is commissioned in accordance with IEC 61133:2016.

Other circuits of voltage level III, auxiliary or control circuits of voltage levels II and I that do not feature sufficient insulation based upon the contact line voltage (e.g. that feature insulation for their voltage band and are thus only functional insulation) are assigned to the above-mentioned circuits and shall be tested together with these circuits. The testing of functional insulation is not an integral part of this document.

The test shall be performed successively from high to low voltage levels/bands. Circuits that have already been tested are not reconnected to the other circuits to prevent repetitive tests and the distortion of insulation resistance measurements owing to parallel circuits of insulation resistances.

The test is carried out:

- a) after having excluded those components supplied at voltages of band III and that have already been tested at factories before delivery, and after having connected together all remaining circuits, belonging to one insulation level of band III. This does not apply to supplementary insulations that are implemented only when mounted on the vehicle between component/device housing and the vehicle mass (chassis). A list of such components shall be given as well as documentation of a separate test carried out by the manufacturer. These documents may be type test logs, routine test logs or declarations of conformity (routine tests in accordance with product standards may yield lower values for the test period in item c)),
- b) having connected to earth all remaining circuits and components of the electrical equipment of the trolley bus,
- c) by applying a power frequency test voltage U_a as shown in IEC 62497-1: 2010, Table B.1,

- d) by carrying out the test between the above-mentioned circuits and components and the intermediate masses connected to the vehicle mass (chassis) (see Figure 3 a)),
- e) by repeating the test between the interconnected intermediate masses and the vehicle mass (see Figure 3 b)); the circuits of voltage level III stay insulated, the connection between the intermediate masses and the remaining circuits is removed,
- f) by repeating the test between the intermediate masses insulated from each other (refer to Figure 3 c)).

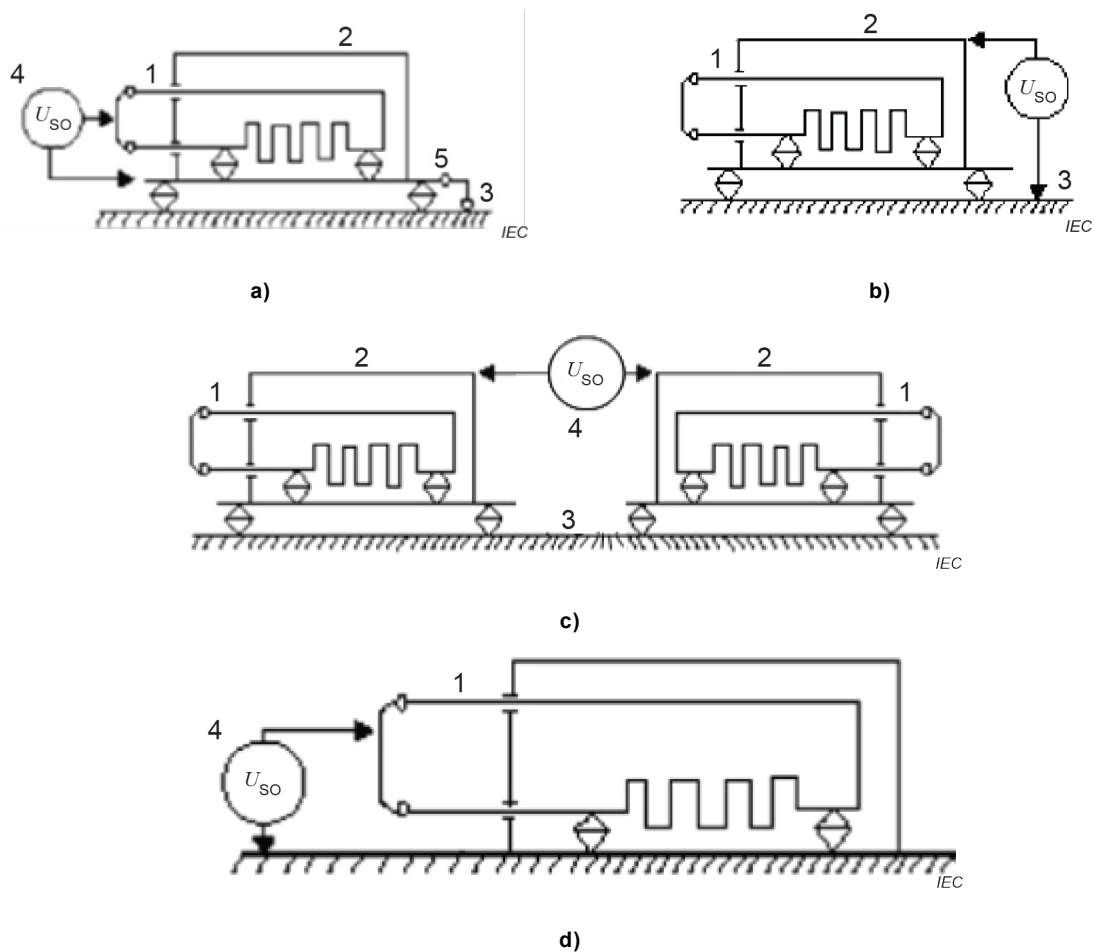
6.2.3 Separate source applied voltage tests on circuits and components fed at voltages of the band III insulated from the overhead contact line

The circuits and the components fed at voltages of band III, but not fed directly by the voltage of the line, featuring single or double insulation from the vehicle mass (chassis), shall be tested as specified above, (see Figure 3 d)) at a power frequency test voltage of U_a (see IEC 62497-1: 2010, Table B.1), applied between the respective circuits and the vehicle mass (chassis).

Connections to the vehicle mass (chassis) to ensure functions of insulated supply networks that are double insulated from circuits supplied with overhead contact line voltage shall be separated from the vehicle mass (chassis) for this test. These include, e.g. in the case of three-phase supply networks, the connection from the neutral point of the network to the vehicle mass (chassis) to reduce the line voltages with respect to the vehicle mass (chassis), to implement an equipotential bonding system with and without leakage current monitoring as well as insulation monitoring.

It is assumed that the values of this double insulation refer to the contact line voltage.

After repair or if the withstand voltage test failed, the second test shall be carried out at 85 % of U_a to reduce the stress by the test for the insulation.



Key

- 1 circuit or electrical component
- 2 intermediate mass
- 3 vehicle mass (chassis)
- 4 voltage generator
- 5 equipotential bonding and grounding

Figure 3 – Test circuits

6.2.4 Separate source applied voltage tests on circuits and components fed at voltages of the band II

The circuits and the components supplied at voltages of band II shall be subjected to power frequency voltage test, on new material, when the vehicle is commissioned in accordance with IEC 61133:2016.

It is assumed that the values of these circuits generally feature double insulation from circuits that are supplied with contact line voltage, with reference to the contact line voltage (refer also to 6.2.2). The test is carried out

- a) after having excluded those components supplied at voltages of band II and that have already been tested at factories before delivery, and after having connected all remaining circuits belonging to one insulation level of band II. A list of such components as well as the documentation of a separate test carried out by the manufacturer shall be available. These documents may be type test logs, routine test logs or declarations of conformity (routine tests according to product standards may yield lower values for the test period of item c)),

- b) having connected to each other and grounded all remaining circuits and components of the electrical equipment of the trolley bus, supplied on a lower voltage level,
- c) by applying a power frequency test voltage U_a between the circuits and components specified above and the vehicle mass (chassis); the value for U_a is listed in IEC 62497-1:2010, Table B.1.

6.2.5 Tests of the insulation of entrance areas

The design of the structure and a visual inspection of the entrance areas, together with the test reports or certificates of conformity of the insulating layer (e.g. corresponding to IEC 61111), are the criteria for acceptance.

The suitability of materials for insulation of entrance areas regarding dielectric and mechanical properties shall be demonstrated by appropriate documents.

The visual inspection shall be carried out by qualified electricians. During visual inspection, the material shall be accurately examined for any damage that affects the dielectric properties, such as fractures, cracks or pinholes.

NOTE In Europe, qualified electricians are defined in EN 50110-1:2013, 3.2.4.

Adequate clearance and creepage distances shall be confirmed according to IEC 62497-1:2010.

6.2.6 Insulation resistance values for circuits and components supplied at band III voltages from the line voltage

The following insulation resistance measurements shall be carried out:

- a) between the vehicle mass (chassis) and all the interconnected circuits and components supplied at the line voltage (see Figure 4 a));
- b) between each intermediate mass and all the interconnected circuits supplied at line voltage (see Figure 4 b));
- c) between the vehicle mass (chassis) and each intermediate mass (see Figure 4 c));
- d) between each intermediate mass and all other intermediate masses (see Figure 4 d)).

The tests, to be performed with the conditions shown in 6.2.7, are considered passed when the insulation resistance R , measured in a dry state, satisfies the condition:

$$R \geq 10 \text{ M}\Omega$$

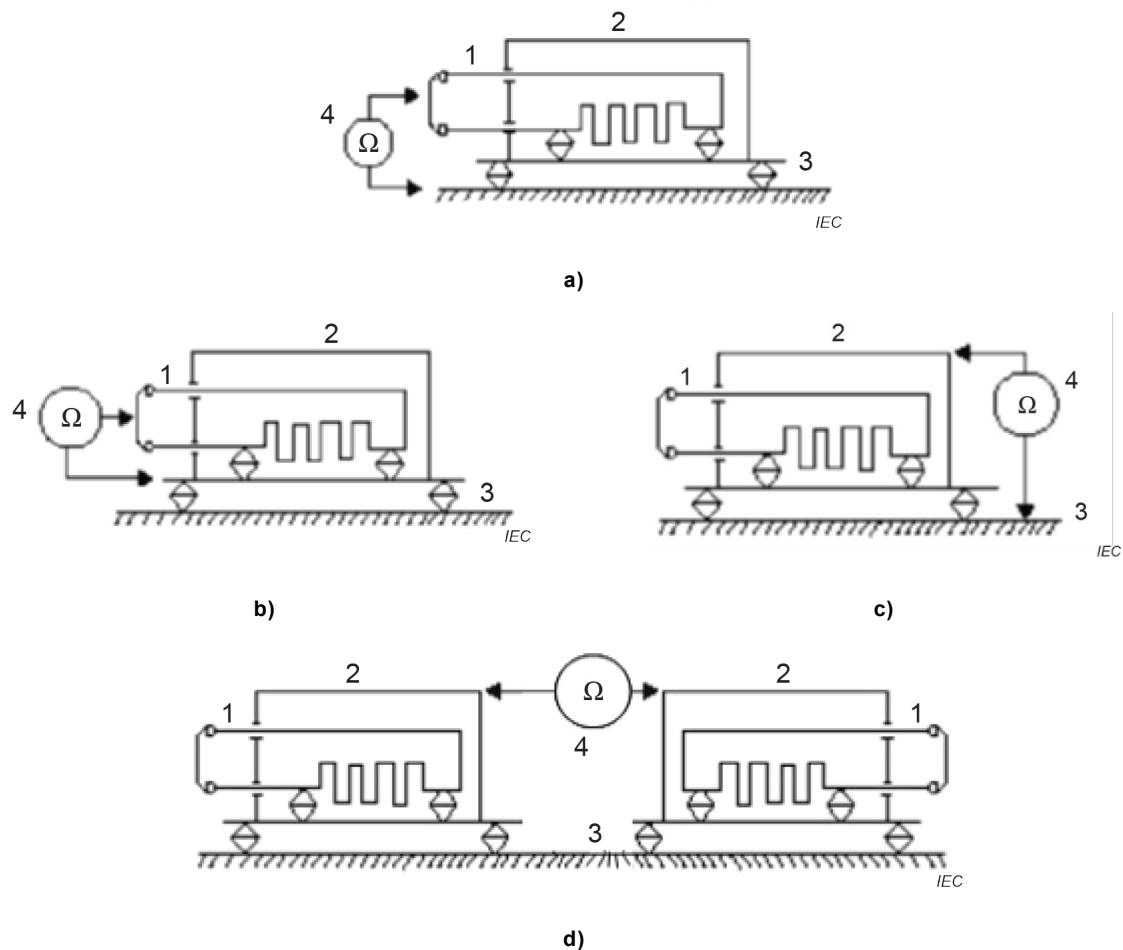
6.2.7 Insulation resistance tests for circuits and components supplied at the line voltage

The insulation resistance tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. Referring to the tests under a) and b) of 6.2.6, all circuits and electrical components shall be connected; therefore, all switches and contactors concerned shall be positioned such that all parts of the electrical installation directly supplied at the line voltage are energized during the test. This can be carried out by following operating instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by an integrated test function of the system.

Before testing, the mass's connection of the leakage detector (see 5.1.6) shall be removed if this is specified by the manufacturer of the device for this measurement.

The measurement shall be carried out with a megaohmmeter with a generator (that is part of the instrument) for 1 000 V DC.

According to the measurement type, the megaohmmeter shall be connected as indicated in Figure 4 a), b), c) or d).



Key

- 1 circuit or electrical component
- 2 intermediate mass
- 3 vehicle mass (chassis)
- 4 measuring instrument

Figure 4 – Megaohmmeter connection

6.2.8 Insulation resistance values for circuits and components supplied at band III voltages insulated from the line voltage

These circuits and electrical components shall be submitted to the measurement of the insulation resistance to the vehicle mass (chassis) even if they are insulated supply networks featuring double insulation from the contact line that are connected to the vehicle mass (chassis) to ensure functions (refer also to 5.2.4.2 and 6.2.3). The test is considered passed when the insulation resistance R , measured in a dry state, satisfies the following condition:

$$R \geq 10 \text{ M}\Omega$$

When an intermediate mass is present for constructional reasons in these installations, the criteria shown in 6.2.6 b) and c) apply. The resistance values for these intermediate masses shall satisfy the above-mentioned condition.

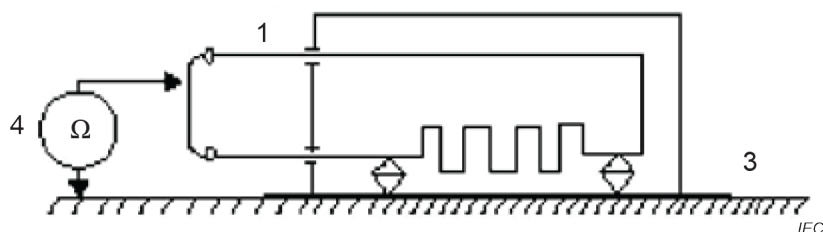
6.2.9 Insulation resistance tests for circuits and components supplied at band III voltages insulated from the line voltage

The insulation resistance tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. All circuits and electrical components shall be connected; therefore, all concerned switches and contactors shall be positioned such that all parts of the electrical installation supplied at band III voltage are energized during the test. This can be achieved by following instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by operating an integrated test function of the system.

Before testing, the mass connection of the leakage current detector (see 5.1.6) shall be removed if this is specified by the manufacturer of the device for this measurement. In this case, a separate periodical test for the leakage detector shall be specified.

The measure shall be carried out with a megaohmmeter with a generator (that is part of the instrument) for 1 000 V DC.

The megaohmmeter shall be connected as indicated in Figure 5.



Key

- 1 circuit or electrical component
- 3 vehicle mass (chassis)
- 4 measuring instrument

Figure 5 – Megaohmmeter connection

When intermediate masses are present, the instrument shall be connected as shown in Figures 4 b) and c).

Depending on the provisions (in accordance with IEC 61991), to prevent electrical hazards, if applicable, the insulation resistance test in 6.2.9 can be carried out by following the same procedure specified in the periodical insulation resistance test in 6.4.

6.2.10 Insulation resistance values for circuits and components supplied at a voltage of band II

The insulation resistance between the vehicle mass (chassis) and all the interconnected circuits and components supplied at a voltage of band II shall be measured.

The test is considered passed when the insulation resistance R , measured in a dry state, satisfies the following condition:

$$R \geq 10 \text{ M}\Omega$$

6.2.11 Insulation resistance tests for circuits and components supplied at a voltage of band II

The insulation resistance tests shall be made with the vehicle dry and also when the vehicle is wet if this is required. All circuits and electrical components shall be connected.

taking into consideration the electrical diagram of the vehicle's equipment, all concerned switches and contactors shall be in the position to energize all parts of the electrical installation supplied at band II voltage during the test. This can be achieved by following instructions based on the circuit diagrams of the vehicle or (also to facilitate the periodical test) by operating an integrated test function of the system.

Before testing, the mass connection of the leakage current detector (see 5.1.6) shall be removed if this is specified by the manufacturer of the device for this measurement. In this case, a separate periodical test for the leakage detector shall be specified.

The measurement shall be carried out with a megaohmmeter with a generator (that is part of the instrument) for 1 000 V DC.

The megaohmmeter shall be connected as indicated in Figure 5.

Depending on the provisions (in accordance with IEC 61991) to prevent electrical hazards, if applicable, the insulation test can be carried out by following the same procedure specified in the periodical insulation resistance test in 6.4.

6.3 Overhauled trolley-bus

6.3.1 Tests and verification of the electrical equipment

Upon new commissioning of the overhauled vehicle, the verifications of dielectric properties required under 6.2.1 to 6.2.4 shall be repeated with values reduced to 85 % of U_a .

6.3.2 Measurements and value of the insulation resistance

The insulation resistance tests described in 6.2.7, 6.2.9 and 6.2.11 shall be carried out on the overhauled portion of the electric installation and at the associated voltage band.

The tests are considered successful when the insulation resistance is at least 1/3 of the values required for a new vehicle.

6.3.3 Insulation resistance tests

See the requirements in 6.2.7, 6.2.9 and 6.2.11.

6.3.4 Trolley bus after minor or maintenance repairs

Depending on the range of repair, tests shall be carried out corresponding to the subclauses of 6.3. In particular, for components tested in the workshop on product standards, only the on-board insulations shall be tested. For further tests, refer to 6.4.2.

6.4 On-duty trolley-bus (periodic checks)

6.4.1 Insulation decay and provisions required

During service, the insulation can suffer decay due to several external causes (mud, rain, etc.), gradual wear or fault; this decay, beyond a given limit, shall be revealed by the leakage detector (see 5.1.6). To provide a suitable safety margin of the insulation level of the vehicle, two provisions are necessary:

- verifications and periodical checks according to 6.4.2 and 6.4.3. When the verified insulation resistance results are equal to or lower than those indicated in Table 5, the vehicle shall be immediately submitted to maintenance before being put into service again;
- verification of the efficiency of the leakage detector, if any, as per 6.5.3. When the verified insulation resistance value results are equal to or lower than what is required in 6.5.2, the vehicle shall be immediately submitted to maintenance before being put into service again.

6.4.2 Periodical checks and tests of the insulation during maintenance

Repairs or modifications to the vehicle shall not result in a reduction of safety relative to its original state. In particular, this concerns:

- creepage distances and clearances,
- protection measures against electric shock,
- protection against ingress of moisture and dust,
- protection measures against mechanical and other hazards,
- the functional sequence of the software, if required.

The qualified electrician responsible for the test shall decide whether additional tests are required to demonstrate that the level of safety has been maintained.

To be observed during the final visual inspection:

- damage to connecting cables;
- damage to insulation;
- proper selection of wires and connectors;
- state of the terminals and wires;
- damage to bend protection and strain relief;
- damage to enclosure and protective covers;
- signs of prohibited manipulation or changes;
- degradation of safety by corrosion or deterioration of materials.

The insulation of the electrical equipment of the vehicle (or a part of the insulation system) should be verified based upon the operator's maintenance plan or following a fault.

These verifications shall be preceded by a visual inspection to check for any deterioration which could prevent operation and reduce safety.

Successively, the intermediate masses shall be individually checked using the device mentioned in 5.1.7 and, if required, the insulation resistance of the electrical equipment, of the systems or of the sub-systems concerned shall be measured. If available, a specific test board as described in Clause A.9 may be used for this purpose.

6.4.3 Periodical checks and tests of the insulation

The law in some countries prescribes annual visits, checks and tests on the rolling stock. Within the scope of these events, the insulation resistance measurements shall be carried out in accordance with 6.2.7, 6.2.9 and 6.2.11.

Tests are described in 6.2.7, 6.2.9 and 6.2.11 and for the minimum values of the insulation resistance in dry conditions, the following minimum values are recommended:

- for each single insulation $\geq 500 \text{ k}\Omega$;
- for parallel circuits of all double insulations $\geq 1 \text{ M}\Omega$ (entire vehicle).

Table 5 – Summary of electric tests

Voltage band	New vehicle	Overhauled vehicle	On-duty vehicles
Band II	Test voltage U_a based on $U_{Nm}U_{Ni}$ (refer to IEC 62497-1: 2010 and IEC 62497-1:2010/AMD1:2013, Table B.1) ^a	85 % test voltage U_a based on $U_{Nm}U_{Ni}$ (refer to IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table B.1)	
	Insulation $R \geq 10 \text{ M}\Omega$ (megaohmmeter 1 000 V DC)	Insulation $R \geq 3,3 \text{ M}\Omega$ (megaohmmeter 1 000 V DC)	Insulation $\geq 500 \text{ k}\Omega$ (megaohmmeter 1 000 V DC)
Band III	Test voltage U_a based on $U_{Nm}U_{Ni}$ (refer to IEC 62497-1: 2010 and IEC 62497-1:2010/AMD1:2013, Table B.1)	85 % test voltage U_a based on $U_{Nm}U_{Ni}$ (refer to IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table B.1)	
	Insulation $R \geq 10 \text{ M}\Omega$ (megaohmmeter 1 000 V DC)	Insulation $R \geq 3,3 \text{ M}\Omega$ (megaohmmeter 1 000 V DC)	Insulation $\geq 500 \text{ k}\Omega$ (megaohmmeter 1 000 V DC)
^a The manufacturer shall supply for each group of components of the same voltage band, the rated ~~insulation~~ impulse voltage $U_{Nm}U_{Ni}$ in order to assess the test voltage U_a given in IEC 62497-1:2010 and IEC 62497-1:2010/AMD1:2013, Table B.1.			

6.5 Leakage detectors (overhaul, definitions, thresholds)

6.5.1 Operating voltages and temperature ranges

The leakage detecting apparatus shall operate correctly in the range of from $0,67 U_n$ to $1,2 U_n$ referred to the nominal line voltage (see 4.1.2), specified in IEC 60850.

The same applies in the voltage range of $0,70 U_n'$ to $1,15 U_n'$, specified in IEC 60571, when the apparatus is supplied by the battery of the vehicle network (see 5.4) having the nominal voltage U_n' .

Characteristics of the supply voltage as described in ISO 16750-2 for motor vehicles shall not impact the functionality of the detector.

The temperature range shall comply with IEC 62498-1 according to environmental conditions and the installation location in the vehicle.

6.5.2 Operation and alarm of the detector

As indicated in 5.1.6, the leakage detector, if any, shall give an alarm signal, optical and acoustical, at the intervention level (threshold) specified in 6.5.3.

To prevent faulty activation at sections, switches and section insulators of the overhead contact line, the device shall not take into consideration short-term reductions in the insulation resistance as well as exceedances of the leakage current or of the touch voltage. For the single monitoring of the vehicle mass (chassis) (i.e. complete insulation), the time-dependent limit values from IEC TS 60479-1 and IEC 62128-1 shall apply. If basic and supplementary insulation are independently monitored to identify the need for unscheduled maintenance, longer time limits may be specified by the operator.

If the value falls short of the static limit value, the vehicle shall be immediately removed from service, according to the procedures stated by the operator, for undergoing the verifications and repairs in accordance with 6.4.2.

The following subclauses show that a leakage detector, similar to other insulated applications, can be used to increase the availability and/or for preventative maintenance. In this case, safety is ensured by the double insulation instead of equipotential bonding/grounding.

6.5.3 Limits and calibration of the detector

6.5.3.1 General

Limit values for perceptual thresholds, pain thresholds and hazard threshold as a function of the leakage current are specified in IEC TS 60479-1 and, based upon this, the thresholds assuming voltage-dependent transitional and body resistance values as a function of the touch voltage are specified in IEC 62128-1.

To prevent accidents caused indirectly by leakage currents or touch voltages (e.g. falling), the static limits of the perceptual thresholds shall be applied for testing.

The limits for current, voltage and resistance specified refer to the monitoring of the overall insulation of the vehicle, made up of a parallel circuit of all the double insulations. For the monitoring of all the basic and/or supplementary insulations by monitoring of the intermediate masses described in 5.1.7, other/higher values may be useful and shall be specified by the manufacturer together with the relevant check.

6.5.3.2 Leakage current monitoring

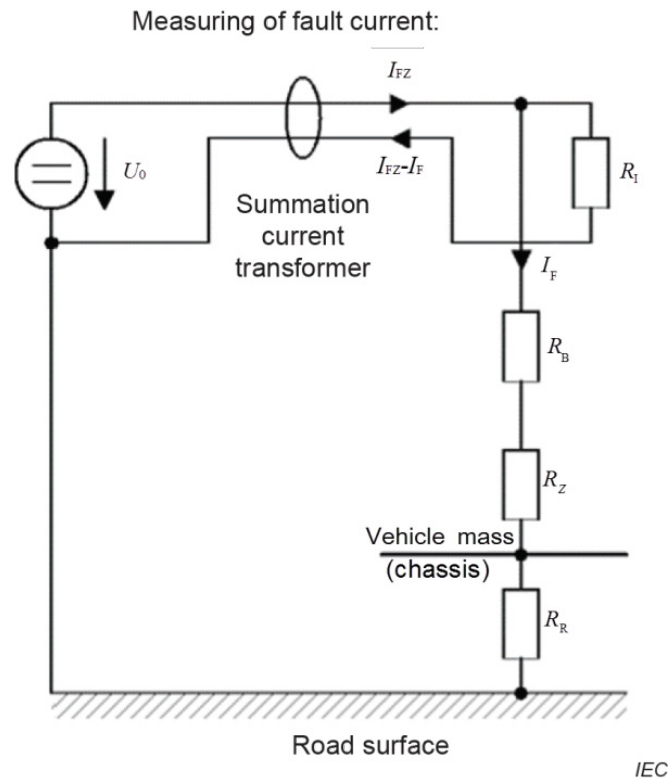
The static limit value for the leakage current I_F , derived from IEC TS 60479-1, is 2 mA for direct current and 0,5 mA for alternating current. For higher frequencies, IEC 60479-2 applies.

The summation current transformer used for monitoring shall meet extremely high demands owing to the high system currents (> 500 A) and low limit values (< 2 mA). Transient events and capacitive coupling may easily cause spurious tripping.

Owing to the indeterminate transition resistance to the ground, the fault may be detected in the worst case only when the leakage is caused by a human being. System components on the supply side of the current transformer and the transformer directly are not monitored.

Intermediate masses cannot be monitored using this method.

Leakage current monitoring circuit is shown in Figure 6.



Key

- U_0 no-load voltage of overhead contact line
- R_B resistance of basic insulation of vehicle
- R_Z resistance of supplementary insulation of vehicle
- R_i internal resistance of trolley bus installation
- I_{FZ} total current of vehicle
- I_F fault current of vehicle
- R_R transition resistance of tyres from vehicle to surface

Figure 6 – Leakage current monitoring

6.5.3.3 Insulation resistance monitoring

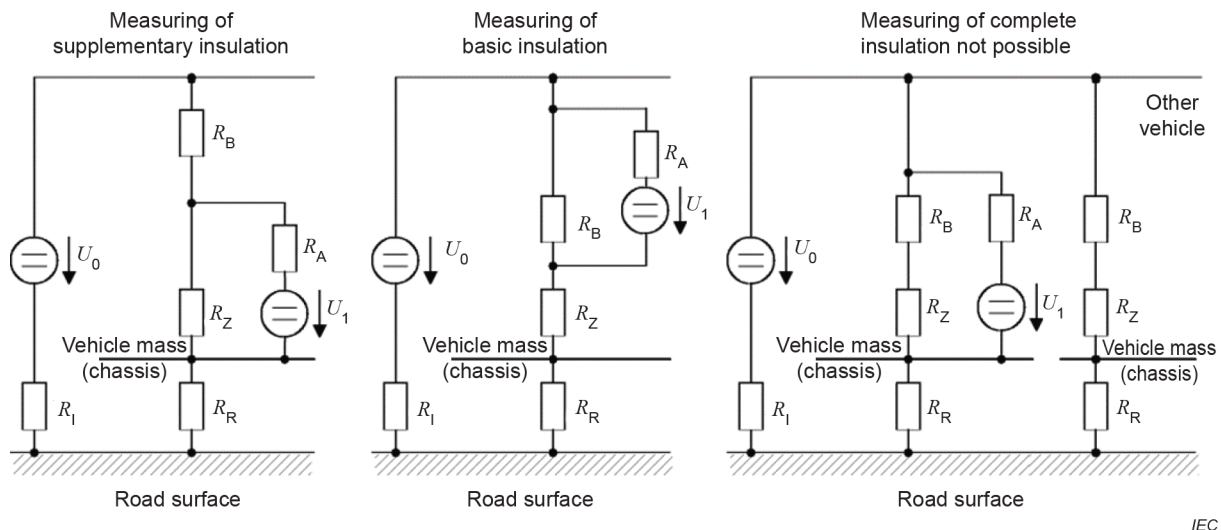
The static limit value for the minimum insulation resistance $R_{\min}$ results from the nominal voltage and the limit value for the leakage current with sufficient margin to the limit of 500 kΩ in 6.4.3 for single insulations:

$$R_{\min} = U_n / 2 \text{ mA}.$$

The insulation resistance is determined by applying a measuring voltage that generates a measurement current. The voltage is applied to the insulation distance via coupling resistances that increase the internal resistance of the measuring instrument.

This monitoring principle can only sense one path or the summary of several paths of basic or supplementary insulations. Bridging the path by means of the coupling resistance, which shall be chosen to be as small as possible to reduce the measuring time, is disadvantageous. Parasitic capacitance or wiring capacitance will increase the response time.

The overall insulation cannot be sensed directly since the insulation resistance values of the traction substations, of the contact wire and of other vehicles (all switched in parallel) are sensed via the transitional resistance to the ground, which may cause spurious tripping.



Key

- U_0 no-load voltage of overhead contact line
- U_1 measuring voltage
- R_B resistance of basic insulation of vehicle
- R_Z resistance of supplementary insulation of vehicle
- R_R transition resistance of tyres from vehicle to surface
- R_A coupling resistance of insulation monitoring device
- R_I insulation mass resistance of substation and overhead line

Figure 7 – Insulation resistance monitoring

The individual values of all the basic and supplementary insulation systems shall be acquired. The acquisition time depends on the time constant that is determined by the coupling resistance of the acquisition and the capacity of the basic and supplementary insulation of the measuring point.

To determine the overall insulation, a calculation based on the individual values is required, which requires an addition of all the measurement times.

Switch off or separation of the equipment within the time limits, given by IEC 62128-1 or IEC TS 60479-1, is not possible (see also 6.5.2).

Insulation resistance monitoring circuit is shown in Figure 7.

6.5.3.4 Touch voltage monitoring

The static limit for touch voltage is taken from IEC 62128-1 and is 60 V DC or 25 V AC.

Since the voltage limit values in IEC 62128-1 do not drop below the perceptual threshold under all circumstances, the lower values should be targeted at the response threshold of the touch voltage. The internal resistance of the voltage acquisition shall be chosen according to the leakage current threshold.

If the voltage is measured via electrically conducting sliding wires, the acquisition depends on the contact to ground, its conductivity and transitional resistances connected in parallel (e.g. tyres).

The circuit for touch voltage monitoring with sliding wires is shown in Figure 8.

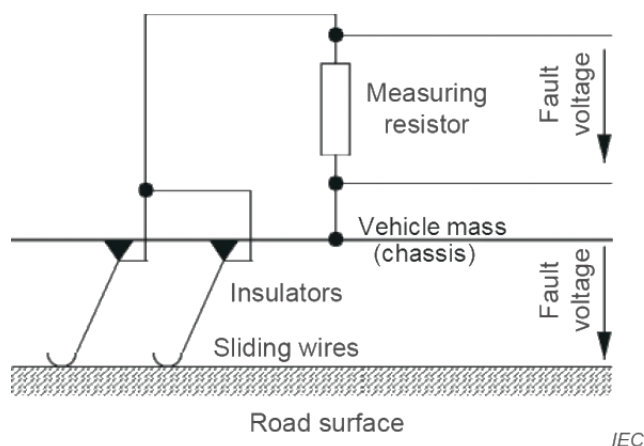
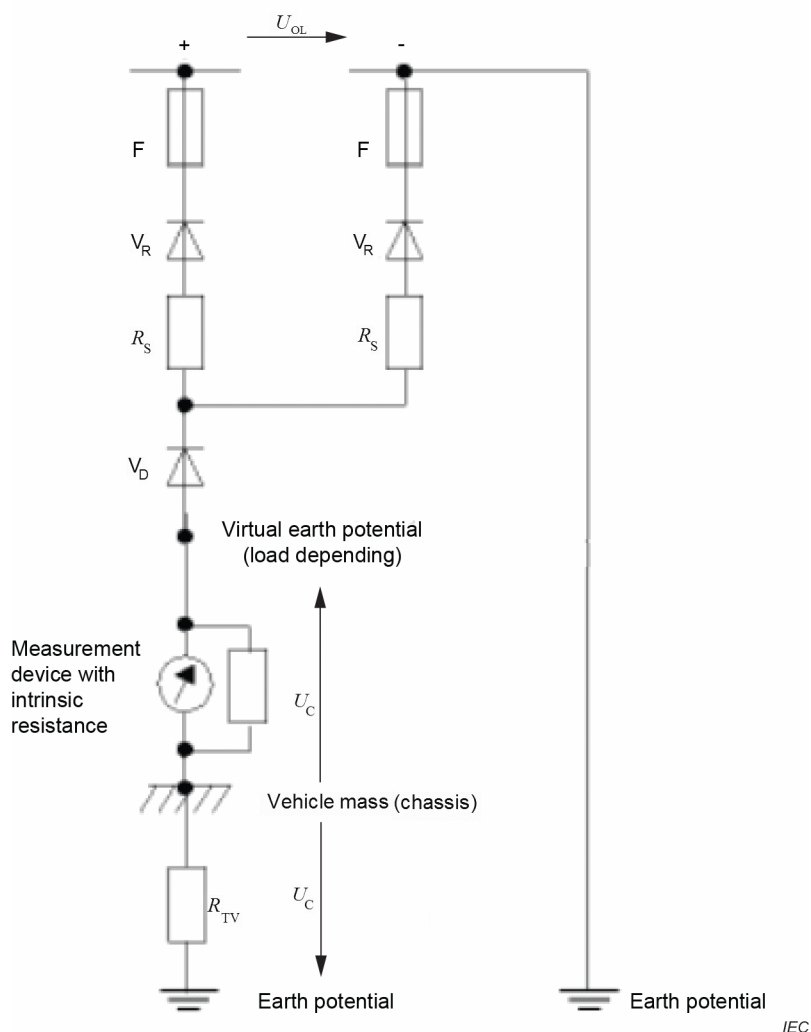


Figure 8 – Touch voltage monitoring with sliding wires

If the voltage is measured indirectly against the grounded pole of the overhead contact line, the voltage between the vehicle and the ground is increased compared to the measured voltage if the overhead contact line is loaded. This effect is due to the voltage drop on the overhead contact line from the vehicle to the next grounding point.

If the individual segments of the overhead contact line are grounded at each power feed (refer also to Figure 10), this voltage drop is split between the conductor and the return conductor and amounts to half the difference between the open-circuit voltage at the power feed and the overhead contact line voltage at the measuring point. Since, in accordance with IEC 60850, the maximum voltage drop is 200 V at 600 V and 250 V at 750 V nominal contact line voltage, values increased by 100 V to 125 V are possible. If the open circuit voltage of the power feeds is absolutely identical, the voltage drop can be compensated by means of a controllable voltage source.

The circuit for touch voltage monitoring with grounded overhead contact line is shown in Figure 9.

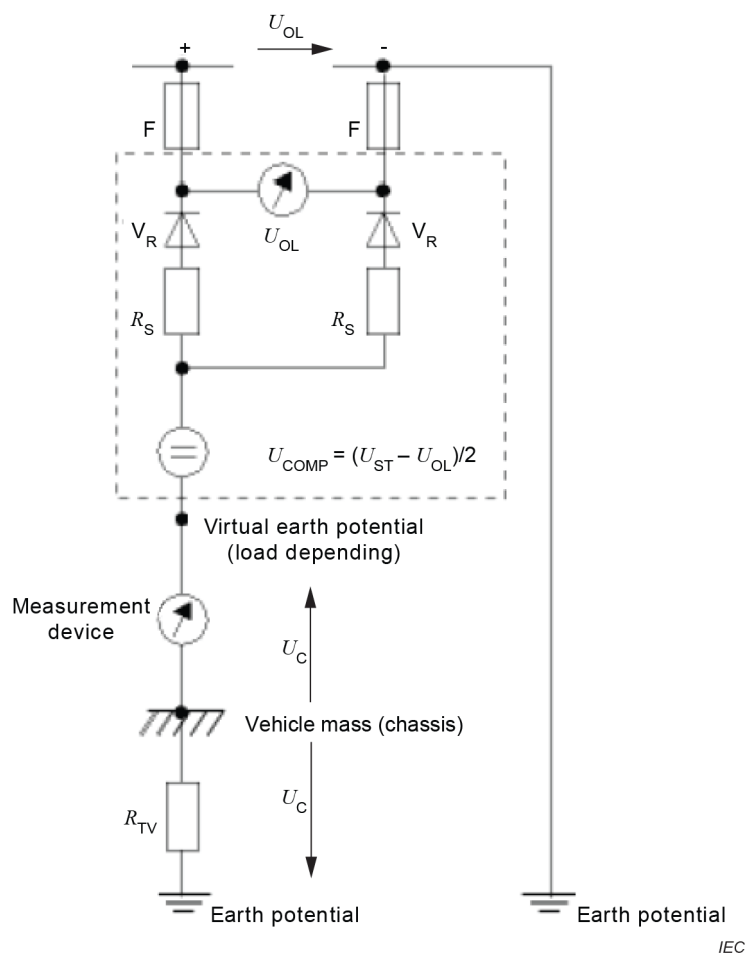


Key

F	2-pole, very low current, DC-circuit-breaker
V_R	rectifier diode
V_D	decoupling diode
R_S	series resistor for current limitation
R_{TV}	transition resistance of tires
U_{OL}	open-circuit voltage of overhead line
U_c	contact voltage

Figure 9 – Touch voltage monitoring with grounded overhead contact line

In the case of indirect measurement against the grounded pole, particular importance is attached to the decoupling from the contact line, especially from the ungrounded pole. Additional measures that prevent the application of a permanent voltage to the vehicle mass (chassis), if a decoupling section fails, shall be provided.

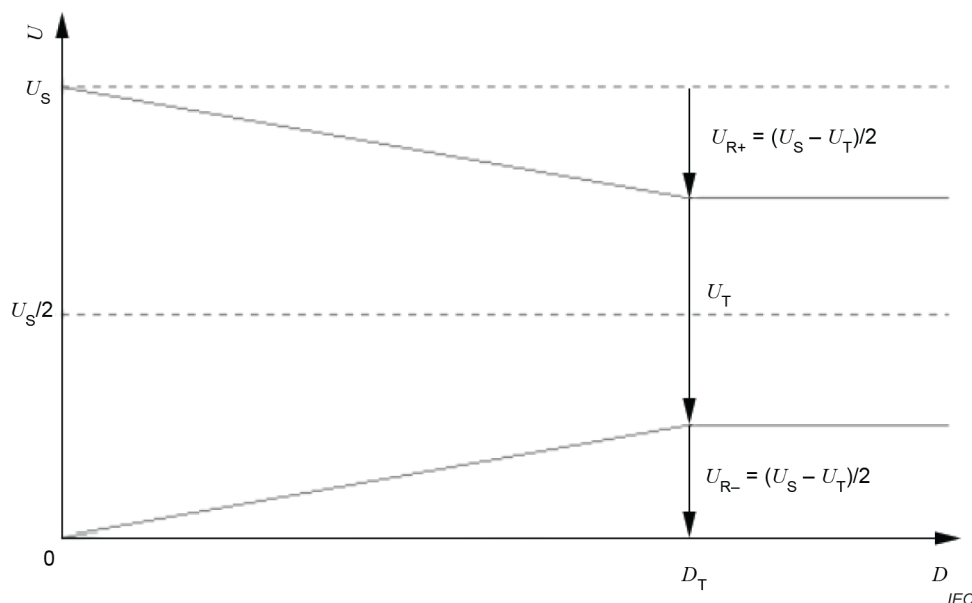


Key

F	2-pole, very low current, DC circuit breaker
V_R	rectifier diode
R_S	series resistor for current limitation
R_{TV}	transition resistance of tires
U_{OL}	voltage of overhead contact line
U_C	contact voltage
U_{COMP}	compensation voltage
U_{ST}	no load voltage of substation

Figure 10 – Compensation of the voltage drop on the grounded overhead contact line

In this case, the internal resistance can be used to limit the potential of the vehicle mass (chassis) relative to the grounded pole of the contact line. Under certain conditions, the effectiveness of this measure can be increased by compensating for the voltage drop shown in Figure 11 by a voltage-controlled voltage source (Figure 10).

**Key**

- U_s open-circuit voltage of substation
- U_T line voltage (detected from trolleybus)
- U_{R+} voltage drop along positive wire
- U_{R-} voltage drop along negative wire
- D_T distance of trolley bus to substation

Figure 11 – Voltage development with a load connected to the overhead contact line

If the overhead contact line is grounded at the traction substations and their open circuit voltage is set absolutely identically, this voltage drop can be compensated for by means of a controllable voltage source.

6.5.4 Periodic efficiency checks

6.5.4.1 General

Particular care shall be given to ascertain that the leakage detector, if any, continues to operate and that the calibration remains within the values required in 6.5.2 and within the associated voltages and currents.

Such verifications shall be carried out not only with a new or overhauled vehicle, but also periodically in accordance with the maintenance plan of the operator and in any case before putting the vehicle into service after repair work caused by an insulation deficiency.

The minimum insulation resistance limits for setting the monitoring are derived from 6.5.3.3: $300 \text{ k}\Omega \pm 45 \text{ k}\Omega$.

The maximum leakage current limits are derived from IEC TS 60479-1: $2 \text{ mA} \pm 0,3 \text{ mA}$.

The maximum voltage limits are derived from IEC 62128-1: $60 \text{ V} \pm 9 \text{ V}$.

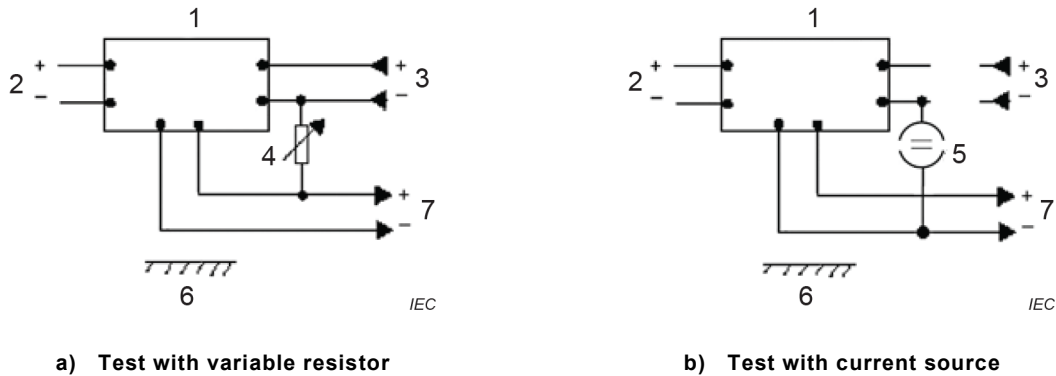
The measurement tolerance is derived from IEC 61557-8: $\pm 15 \%$.

When checking with line voltage, the pertinent safety regulations shall be observed.

NOTE In Europe, the standards of the EN 50110 series are used for this purpose.

6.5.4.2 Checking the leakage current monitoring

For checking purposes, an appropriate current source or a settable resistor, in connection with the system, if applicable, can be used together with the line voltage. The monitor shall respond at a leakage current of 2 mA against ground that is located on the vehicle's side behind the point of measurement.



Key

- 1 leakage detector
- 2 battery voltage
- 3 line voltage
- 4 connect different poles up- and downstream of the device with the variable resistor ($R_{\min}$ = variable leakage resistance externally applied)
- 5 connect equal poles up- and downstream with a current source
- 6 vehicle mass (chassis)
- 7 outgoing line to the vehicle downstream of the measurement

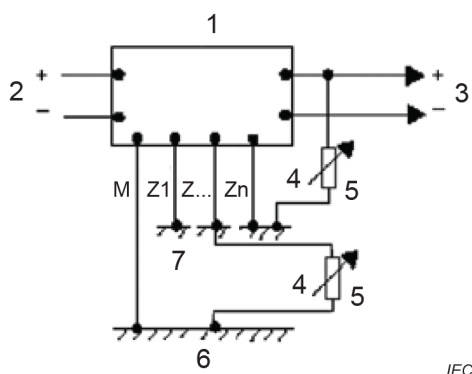
Figure 12 – Function check of the leakage current monitoring

To establish more safety during the test, the test should be carried out with the current source without connection to the overhead line. Figure 12 a) only serves for clarification.

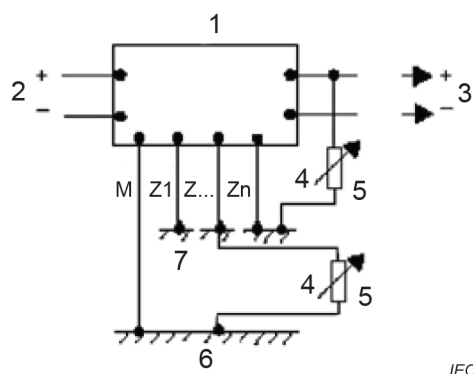
The test is successfully passed when the device responds at $2 \text{ mA} \pm 0,3 \text{ mA}$.

6.5.4.3 Check of the insulation resistance monitoring

For checking purposes, settable resistances (also without connection of the system with the line voltage) can be used. Apart from the individual measurements between the contact line and the intermediate mass and the intermediate mass and the vehicle mass (chassis) (Figure 13), the overall insulation shall be checked by connecting the resistors simultaneously to an intermediate mass. The monitoring shall then respond to the minimum value of the overall insulation defined above.



IEC



IEC

a) Test with overhead line voltage

b) Test without overhead line voltage

Key

- 1 leakage detector
- 2 battery voltage
- 3 line voltage
- 4 connect intermediate mass connectors Z1...Zn with the measurement resistors
- 5 R_{min} = variable resistor externally applied
- 6 vehicle mass (chassis)
- 7 intermediate mass
- M connection between the vehicle mass (chassis) and the measurement resistor

Figure 13 – Function check of the insulation resistance monitor

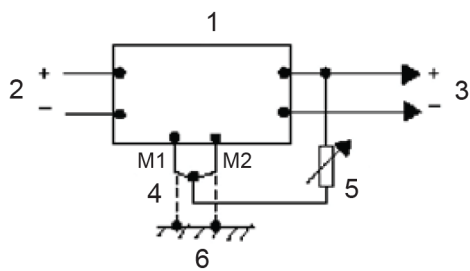
To establish more safety during the test, the test should be carried out without connection to the overhead line. Figure 13 a) only serves for clarification.

The test is successfully passed, when the device responds at $300 \text{ k}\Omega \pm 45 \text{ k}\Omega$.

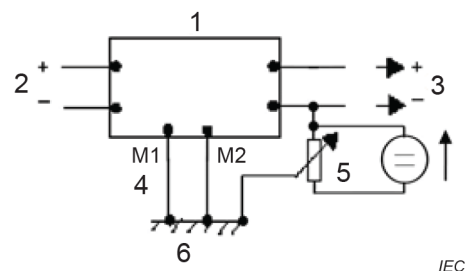
6.5.4.4 Checking the touch voltage monitor

For checking purposes, an appropriate voltage source or a settable resistor in connection with the line voltage can be used. If the transitional resistance to ground cannot be increased by means of insulating mats to the extent that the measurement is falsified, the connection of the measuring instrument to the vehicle mass (chassis) shall be disconnected for the check.

Criteria for the function check with a grounded supply of the test setup and the overhead line voltage as the driving voltage are shown in Figure 14.



IEC



IEC

a) Test with overhead line voltage

b) Test without overhead line voltage

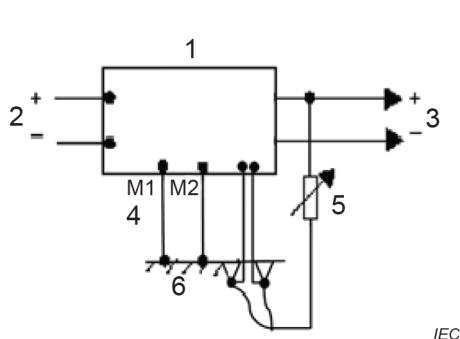
Key

- 1 leakage detector
- 2 battery voltage
- 3 line voltage
- 4 where applicable, disconnect the measurement connections M1/M2 from the vehicle mass (chassis) and short-circuit them
- 5 $R_{\min}$ = variable resistor externally applied between + and the measurement connections or external test voltage source and variable resistor applied between – and the vehicle mass (chassis)
- 6 vehicle mass (chassis)

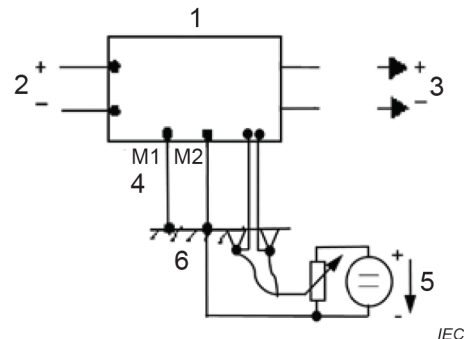
Figure 14 – Function check of the touch voltage monitor with vehicle mass (chassis)

To establish more safety during the test, the test should be carried out with an external voltage source without connection to the overhead line. Figure 14 a) only serves for clarification.

The test is successfully passed when the device responds at $60 \text{ V} \pm 9 \text{ V}$.



IEC



IEC

a) Test with overhead line voltage

b) Test without overhead line voltage

Key

- 1 leakage detector
- 2 battery voltage
- 3 line voltage
- 4 where applicable disconnect the measurement connections M1/M2 from the vehicle mass (chassis) and short-circuit them
- 5 $R_{\min}$ = variable resistor externally applied between + and sliding wires or external test voltage source and variable resistor applied between sliding wires and the vehicle mass (chassis)
- 6 vehicle mass (chassis)

Figure 15 – Function check of the touch voltage monitor with sliding wires

To establish more safety during the test, the test should be carried out with an external voltage source without connection to the overhead line. Figure 15 a) only serves for clarification.

The test is successfully passed when the device responds at $60 \text{ V} \pm 9 \text{ V}$.

Annex A (normative)

Constructional detailed provisions

A.1 General

Considering the specific characteristics of a trolley bus vehicle, it is considered necessary to recall the following points, which shall be carefully considered during the design and manufacture.

A.2 Attachment of the current collection system and other components

Large components and their mounting parts shall be designed to withstand the load as specified by the vehicle manufacturer. Without information, the requirements shall comply with IEC 61373 and ISO 16750-3, if applicable.

The current collection system and the poles to the base shall be fitted and secured in order to prevent disconnection or loss of parts, taking into account shocks due to dewirement of the trolley.

A.3 Insulations

The insulating covers, the interposed insulations, clearance in air and the protection against water penetration shall be adequately designed and maintained. The design of insulation distances is detailed in IEC 62497-1.

IEC 62497-1 provides only minimum values for creepage distances regarding the voltage stress on insulation. Layout of creepage distances in accordance with IEC 62497-1 without additional measures can result in unacceptable insulation resistances resulting in high leakage currents.

For outdoor use on systems without a protecting earth conductor, the manufacturer shall design appropriate creepage distances regarding the environmental data given by the operator, to ensure compliance with the minimum insulation resistance values given in Table 5.

The approval is achieved by visual inspection and measurement of the length of clearances and creepage distances.

The design of insulation systems shall consider carefully pollution degree, form and material. Insulators with grooves, drip edges or installed in environmental protected locations or made of silicone shall be preferred. For protection of insulation in the lower part of the vehicle, splash protection shall be provided to prevent water film formation. A combination of covers and mud flaps to the wheel houses shall be provided.

Insulation in air ducts, in particular in electric warm-air heaters, is susceptible to pollution and, with high air moisture, the insulation resistance of the heaters easily tends to fall below the limits given in Table 5. Therefore, their cleaning shall be included in the maintenance plan (also for reasons of fire safety).

Positioning of external air intakes shall carefully consider the amount of pollution. Water separators with subsequent filtering shall be provided.

A.4 Ventilation

The compartments housing contactors or switching devices, which may produce an arc during breaking, shall be adequately ventilated to avoid accumulation of ionized air. The same precautions shall be used for compartments containing batteries.

Installation spaces for electronic components, having at least a protection degree of IP54 in accordance with IEC 60529, are necessary to be separated from ventilated installation spaces.

A.5 Accessibility

The arrangement of the individual equipment and of cabling shall be designed taking into account the need of accessibility and inspection: the cables shall not create an obstacle to access parts to be calibrated or subject to wear and tear.

A.6 Location of the main circuit breaker

Mounting of the main protection equipment shall ensure that, particularly under fault conditions, the circuit breaker arc does not reach flammable parts. In particular, mounting in the passenger compartment is not allowed.

A.7 Inlet and outlet points of cables

The inlet and outlet points through the vehicle's body and from the conduits under the chassis shall be protected against penetration of water or mud and against the formation of moisture. Degrees of protection and the relevant tests are described in IEC 60529. The aging of sealing materials and gaskets shall be considered.

A.8 Cabling

Particular care shall be given to the routing, anchoring location and spans of cables, to avoid their loosening or abrading owing to vibrations, considering, if any, passages in proximity to metallic edges. The installation instructions of IEC 62995 shall be observed.

A.9 Test terminal board

In order to facilitate the checks and measurements of the electrical insulation, it is advisable to provide a terminal board, on the vehicle, to which all intermediate masses and other components, requiring verification, are connected. This terminal board may be part of the insulation monitoring device in accordance with 5.1.6 or 5.1.7. The design shall be agreed between the operator and the manufacturer.

A.10 Insulation leakage pre-alarm

To give an early indication of insulation deterioration, particularly in the presence of adverse climatic conditions, it is suggested that an insulation leakage pre-alarm be fitted. This device will measure the insulation resistance and will have a threshold of pre-alarm at a value to be agreed with the operator. This device may be considered a complement of the terminal board mentioned in Clause A.9 or of the device described in 5.1.6.

A.11 Equipment connected to different voltage band circuits

In the case of connection to circuits supplied with band I and II voltages, having components supplied with band III voltages, particular attention shall be given to the integrity of terminals and clearances for the cabling. If necessary, additional clamps and protections shall be added, suitable to avoid contact between different voltage bands, even in the case of detachment of the terminals.

For double insulations, in addition to the requirements of IEC 61991, one cause shall not lead to the deterioration of the basic insulation and the supplementary insulation at the same time.

A.12 Segregation of band III circuits

The compartments containing electrical components at band III voltages, placed inside the vehicle, shall be securely closed and protected from unauthorized access. Warning signs in compliance with IEC 61991 shall be mounted on the cover of these compartments.

IEC 60529 requires the protection degree IPXXD within the passenger or the luggage compartments. In areas other than the roof, protection degree IPXXB applies. On the roof, no protection is required, because of protection by distance in accordance with IEC 61991.

A.13 Batteries and other energy storage devices

When operation of the vehicle with or without an overhead contact line is planned with batteries or other energy storage devices, such as capacitors and flywheel storage devices, these devices should be selected among those commonly used in traction and road vehicles (see ECE Regulation No. 100, ISO 6469-1 and ISO 6469-3).

Depending on the mode of operation of the energy storage system, the need of a double insulation shall be verified. Where, during operation (charging or discharging), there is no galvanic isolation from the overhead line, supplementary insulation shall be retrofitted in the mechanical structure as well as for the voltage supply and the signal interfaces of the control electronics.

A galvanically isolated charger and a galvanically separable connection of the traction circuit with an isolating contactor in accordance with 5.2.4.2 is recommended. This increases crash safety and allows battery systems only with basic insulation (battery bus standard).

The selection of energy storage devices shall be made taking into consideration the safety of staff and passengers, and by applying the International Standards relevant for the kind of energy storage device selected. Refer to IEC 61881 series, IEC 60077-1, IEC 62196-1 and IEC 62928.

Special attention shall be paid to additional hazards in the case of an accident. Chemical and thermal effects owing to leakage and short-circuits in the energy storage device shall be taken into account. The partitioning in units with rated voltages < 120 V by use of additional isolation contactors is recommended. The probability of energy release and the energy released will be reduced, as well as the possible touch voltage being reduced to acceptable values.

If applicable, discharging devices shall comply with IEC 61991 and the IEC 61881 series. Corresponding warning signs shall be additionally affixed. The handling of capacitors is described in the IEC 61881 series.

NOTE In Europe, general handling instructions are specified in EN 50110-1.

Recommendations for external charging systems of energy storage devices are specified in ECE Regulation No. 100, IEC 62196-1, and in IEC 61851.