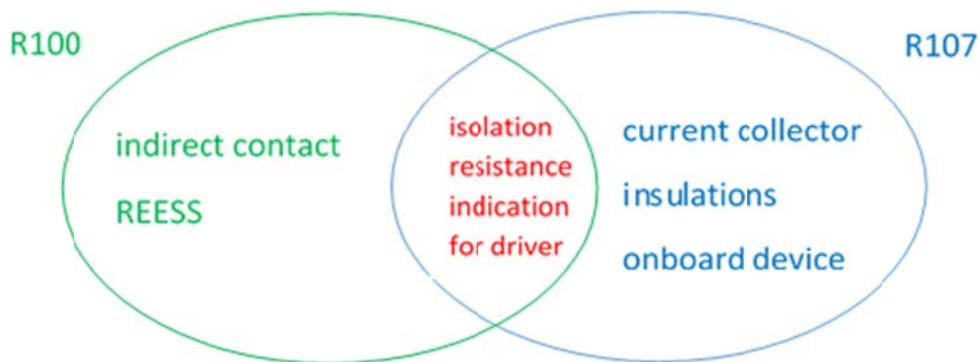


A detailed analysis on the compatibility or incompatibility of the scopes and technical provisions for trolleybuses of UN Regulations Nos. 100 and 107

The text reproduced below was prepared by the expert from Belgium. The proposal by Belgium ECE/TRANS/WP.29/GRSG/2016/05 aimed at removing the amended additional safety prescriptions for trolleybuses from annex 12 of UN Regulation No. 107 for the Construction of M2 and M3 vehicles (R107), and inserting them into UN Regulation No. 100 on Electric Power Trained vehicles (R100), see proposal ECE/TRANS/WP.29/GRSP/2016/07.

The scope and technical provisions for trolleybuses of R100 and R107 are complementary, but not yet fully compatible. This means that both regulations are mutually supplying each other's difference in scope by the appropriate technical provisions, but are not completely consistent in their overlapping provisions. E.g.

- R107 has typical provisions for the external connection of the trolleybus to the overhead contact line, e.g. current collector, different types of insulation and onboard monitoring
- R100 has provisions for indirect contact, the REESS and its connector to the grid.
- R107 and R100 both have provisions for protection degrees against direct contact and require the insulation to be measured.



In these overlaps the inconsistencies are situated :

- R107 and R100 require the same protection degree against direct contact, IPXXD en IPXXB, but R107 refers to ISO 20653:2013 whereas R100 describes the tests in annex 3.
- Where the provisions for insulation in R107 are more stringent than in R100, they actually cover the isolation resistance in R100 for which a technical service might decide not to measure them again. R100 describes a testprocedure (annex 4A), R107 not and the wording is different : R107 uses insulation, whereas R100 uses isolation (resistance).
- A functional problem is the indication to the driver in case of a trolleybus with battery. R100 has a functional safety requirement in which the vehicle movement by its own propulsion system should be impossible as long as the connector of the external electric power supply is physically connected to the vehicle inlet (if the on-board REESS can be externally charged by the user): in a trolleybus however when connected to the overhead contact lines, the battery will be charged whenever there is an excess of power when in motion.
- The orange colour covering for cables which are not enclosed as required by R100, proves to be a minor inconsistency but needs to be dealt with.

Conclusion

The expert from Belgium considers the inconsistencies to be minor, and the respective technical provisions need only clarifications and small modifications in order to become consistent.

In detail (see table p. 3-7)

1. Scope of both regulations is different
 - R107 aims at the general construction of buses (category M2 and M3), whereas R100 concerns now the electrical power train of vehicles of category M and N.
 - R100 specifies additionally that these vehicles are “equipped with one or more traction motor(s) operated by electric power and not permanently connected to the grid”.
 - R107 specifies additionally that by trolleybus, a vehicle electrically driven by energy from external, overhead contact wires is meant. For the purposes of this Regulation, it also includes such vehicles having an additional internal means of propulsion (dual mode vehicles) or having a means of temporary external guidance (guided trolleybuses).
 - Only R100 has provisions for Rechargeable Energy Storage System (REESS).
2. The definitions
 - R107 has definitions specifically for trolleybuses, like line voltage, rated climatic conditions, self-extinguishing material, different insulations and “rated insulation voltage”.
 - R107 and R100 are for the same working or rated voltages, but call it respectively “Voltage Class B” and “High Voltage”.
3. The provisions
 - R107 has provisions specifically for trolleybuses like current collection and over-voltage.
 - R107 has provisions on circuit breaking, wiring and apparatus, the flammability of cases, covers and trays; which were not found in R100.
 - R107 and R100 require the same protection degree against direct contact, IPXXD en IPXXB, but R107 refers to ISO 20653:2013 whereas R100 describes the tests in annex 3.
 - R100 has provisions for connectors and service disconnect (to REESS), whereas R107 has provisions for external insulation as most of the equipment is on the roof
 - Marking : R107 and R100 require the lightning symbol on all Voltage class B or high voltage equipment
 - Colour of cables : R100 requires orange covering for cables which are not enclosed, R107 does not require a colour.
 - For the electrical safety of passengers (which step frequently on and of the bus), R107 requires a double insulation for each circuit energized by an overhead line voltage; there are no double insulation requirements in R100 for persons boarding or leaving a vehicle when the charger coupler is connected.
 - R107 requires on onboard device for permanent monitoring of leakage and automatically disconnection when certain limits are exceeded; R100 requires the onboard monitoring device only for fuel cell vehicles (annex 5)
 - R107 describes the 5 required indicators on the instrument panel in the driver’s compartment, whereas R100 describes the “functional safety” and does not allow motion while charging.
 - Last but not least, the provisions for REESS in R100.
4. The insulation / isolation tests
 - Only R100 requires protection against indirect contact to be tested, by which is meant the contact of persons with exposed conductive parts under protection IPXXB and which becomes electrically energized under isolation failure conditions
 - The required isolation resistance (direct contact in normal use) at a DC power supply is much higher for R107 (10 M Ω for each insulation) then for R100 (+/- 375 k Ω for a typical trolleybus); for which R100 describes a testprocedure (annex 4A), R107 not.
 - R107 requires additional testing of the insulation at AC power supply.

Submitted by the expert from Belgium

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UN Regulation No. 107: General Construction of M2 or M3		UN Regulation No. 100: Electric Power Trained vehicle M and N
Title: Uniform provisions concerning the approval of category M2 or M3 vehicles with regard to their general construction		Uniform provisions concerning the approval of vehicles with regard to specific requirements for the electric power train
Scope: This Regulation applies to every single-deck, double-deck, rigid or articulated vehicle of category M2 or M3		Part I: Safety requirements with respect to the electric power train of road vehicles of categories M and N , with a maximum design speed exceeding 25 km/h, equipped with one or more traction motor(s) operated by electric power and not permanently connected to the grid, as well as their high voltage components and systems which are galvanically connected to the high voltage bus of the electric power train. Part I of this regulation does not cover post-crash safety requirements of road vehicles.
/		Part II: Safety requirements with respect to the Rechargeable Energy Storage System (REESS), of road vehicles of categories M and N equipped with one or more traction motors operated by electric power and not permanently connected to the grid. Part II of this Regulation does not apply to REESS(s) whose primary use is to supply power for starting the engine and/or lighting and/or other vehicle auxiliaries systems.
"Trolleybus" means a vehicle, electrically driven by energy from external, overhead contact wires. For the purposes of this Regulation, it also includes such vehicles having an additional internal means of propulsion (dual mode vehicles) or having a means of temporary external guidance (guided trolleybuses).		/
1.1. "Line voltage" means the voltage provided to the trolleybus from the external power supply. Trolleybuses shall be designed to operate at a rated line voltage of ...		2.16. "External electric power supply" means an alternating current (AC) or direct current (DC) electric power supply outside of the vehicle.
1.2. The electrical circuits of a trolleybus are classified according to their rated voltage in the following classes: 1.2.1. "Voltage Class A" means a: Rated voltage ≤ 30 V AC; and Rated voltage ≤ 60 V DC. 1.2.2. "Voltage Class B" means a: 30 V AC < rated voltage $\leq 1,000$ V AC; and 60 V DC < rated voltage $\leq 1,500$ V DC.		2.17. "High Voltage" means the classification of an electric component or circuit, if its working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (rms).
1.3. Rated climatic conditions		/
1.4. "Self-extinguishing material" means a material that does not continue to burn when the ignition source is removed.		/
1.5. "Insulation": there are different types of insulation: 1.5.1. Functional insulation: ensures the functionality of the equipment;		2.33. "Solid insulator" means the insulating coating of wiring harnesses provided in order to cover and protect the live parts against direct contact from any

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<p>1.5.2. Basic insulation: protects persons from electrical hazards in systems with protective bonding;</p> <p>1.5.3. Supplementary insulation: protects persons from electrical hazards in systems without protective bonding;</p> <p>1.5.4. Double insulation: combination of basic and supplementary, each individually testable by a metallized intermediate layer.</p>	<p>direction of access; covers for insulating the live parts of connectors, and varnish or paint for the purpose of insulation.</p>
1.6. "Rated insulation voltage"	/
2. Current collection	/
3. Traction and auxiliary equipment	
3.1 Electrical components installed on the trolleybus shall be protected against over-voltage and short-circuit current. The protection shall preferably be assured by circuit breakers that are reset automatically, remotely or manually.	/
3.2. Electrical components shall be protected against commutation or atmospheric over-voltage.	/
3.3. Circuit breakers shall provide interruption of particular damaged circuits.	/
3.4. If any circuit includes a single-pole circuit breaker, it shall be installed in the positive wire of the circuit.	/
3.5. All electrical circuits and circuit branches of voltage class B shall be of dual wiring. The trolleybus body may be used as a conductor for protective bonding of circuits, double insulated from the line voltage, of voltage class B. It also may be used as the return connection for voltage class A circuits.	/
3.6. Battery cases, covers and trays shall be made of non-flammable or self extinguishing materials.	/
3.7. Electrical components connected to the line voltage shall have, in addition to their basic insulation, a supplementary insulation from the trolleybus body, the onboard power supply and signal interfaces.	/
For protection of current conducting parts and metallized intermediate layers inside the passenger compartment or luggage compartment, the protection degree IPXXD shall be provided (according to ISO 20653:2013).	<p>Protection against direct contact (<i>with conductive parts intended to be electrically energized in normal use</i>)</p> <p>5.1.1.1. For protection of live parts inside the passenger compartment or luggage compartment, the protection degree IPXXD (<i>as defined in annex 3</i>) shall be provided.</p>
For protection of current conducting parts and metallized intermediate layers in areas other than the passenger compartment or luggage compartment and not on the roof, the protection degree IPXXB shall be satisfied (according to ISO 20653:2013).	5.1.1.2. For protection of live parts in areas other than the passenger compartment or luggage compartment, the protection degree IPXXB (<i>as defined in annex 3</i>) shall be satisfied.
For protection of current conducting parts and metallized intermediate layers on	/

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the roof with protection by distance, no protection degree is required.	
3.7.1. External insulations, e.g. on the roof and at the traction motor with occasional conductivity and regular cleaning, shall have a minimum clearance of 10 mm. ...	/
3.7.2. Voltage class B equipment shall be marked with the lightning symbol. The symbol background shall be yellow, the bordering and the arrow shall be black. ...	5.1.1.4.1. In the case of a REESS having high voltage capability the symbol shown below shall appear on or near the REESS. The symbol background shall be yellow, the bordering and the arrow shall be black. ...
The symbol shall also be visible on enclosures and barriers, which when removed, expose current conducting parts of voltage class B circuits. Accessibility and removability of barriers/enclosures should be considered when evaluating the requirement for the symbol.	5.1.1.4.2. The symbol shall also be visible on enclosures and barriers, which, when removed expose live parts of high voltage circuits. This provision is optional to any connector for high voltage buses. This provision shall not apply to any of the following cases: (a) Where barriers or enclosures cannot be physically accessed, opened or removed; unless other vehicle components are removed with the use of tools; (b) Where barriers or enclosures are located underneath the vehicle floor.
<i>no provision, but high voltage cables are traditionally black</i>	5.1.1.4.3. Cables for high voltage buses which are not located within enclosures shall be identified by having an outer covering with the colour orange.
/	Protection against indirect contact (<i>under protection degree IPXXB and with conductive part becoming electrically energized under isolation failure conditions</i>) 5.1.2.2. The resistance between all exposed conductive parts and the electrical chassis shall be lower than 0.1 ohm when there is current flow of at least 0.2 amperes. This requirement is satisfied if the galvanic connection has been established by welding.
3.8. The current conducting parts of electrical components, with the exception of current collectors, surge arrestors and traction resistors, shall be protected against moisture and dust.	/
3.9. Means shall be provided for a periodic resistance test to be conducted on each basic and supplementary insulation of components with double insulation. With a new and dry trolleybus, the insulation resistance of electrical circuits at a test voltage of 1,000 V DC shall not be less than: 3.9.1.For each basic insulation: 10 MΩ; 3.9.2.For each supplementary insulation: 10 MΩ; 3.9.3.For the overall double insulation: 10 MΩ.	Isolation resistance 5.1.3.1. Electric power train consisting of separate Direct Current- or Alternating Current-buses If AC high voltage buses and DC high voltage buses are galvanically isolated from each other, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 Ω/volt of the working voltage for DC buses, and a minimum value of 500 Ω/volt of the working voltage for AC buses. The measurement shall be conducted according to Annex 4A "Isolation resistance measurement method for vehicle based tests".

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	<p>5.1.3.2. Electric power train consisting of combined DC- and AC-buses If AC high voltage buses and DC high voltage buses are galvanically connected isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 500 Ω/volt of the working voltage. However, if all AC high voltage buses are protected by one of the 2 following measures, isolation resistance between the high voltage bus and the electrical chassis shall have a minimum value of 100 Ω/V of the working voltage:</p> <p>(a) Double or more layers of solid insulators, barriers or enclosures that meet the requirement in paragraph 5.1.1. independently, for example wiring harness; (b) Mechanically robust protections that have sufficient durability over vehicle service life such as motor housings, electronic converter cases or connectors; The isolation resistance between the high voltage bus and the electrical chassis may be demonstrated by calculation, measurement or a combination of both. The measurement shall be conducted according to Annex 4A "Isolation resistance measurement method for vehicle based tests".</p>
3.10. Wiring and apparatus	/
<p>3.10.12. Each of the insulations of voltage Class B equipment onboard the trolleybus shall be tested with an AC power supply at test frequency of 50 - 60 Hz for 1 minute. The test voltage (U_{Test}) for wiring and components at the trolleybus shall be: Basic insulation: $U_{Test} = 2 \times U_{Nm} + 1,500 \text{ V}$ Supplementary Insulation: $U_{Test} = 1.6 \times U_{Nm} + 500 \text{ V}$ For circuits double insulated from overhead line voltage, the test voltage (U_{Test}) shall be at least 1,500 V, or: Basic Insulation: $U_{Test} = 2 \times U_{Nm} + 1,000 \text{ V}$ The equivalent DC test voltage is $\sqrt{2}$ times the AC value. Reinforced insulation in trolleybuses is not allowed for circuits directly connected to overhead line.</p>	/
4. Electrical safety of passengers and crew	
4.1. In a trolleybus, each circuit energized by an overhead line voltage shall have double insulation of the vehicle chassis.	<p>5.1.3.4. Isolation resistance requirement for the coupling system for charging the REESS For the vehicle inlet intended to be conductively connected to the grounded external AC power supply and the electrical circuit that is galvanically connected to the vehicle inlet during charging of the REESS, the isolation resistance between the high voltage bus and the electrical chassis shall be at least 1 MΩ when the charger coupler is disconnected. During the measurement, the traction battery may be disconnected.</p>

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4.2. The influence of dynamic charge currents, caused by capacitive couplings between voltage class B equipment and electric chassis, shall be reduced by the protective impedance of insulating materials used in entrance areas. Stanchions and handrails at doorways, door panels and handles, mobility aid ramps and the first steps shall be made of insulating material, or covered with mechanical durable insulation or insulated from the trolleybus body.	/
4.3. The trolleybus shall be equipped with an onboard device for permanent monitoring of leakage current or voltage between the chassis and the road surface. The device shall automatically disconnect the high voltage circuits from the contact system (when trolleybus is stationary) if the leakage current exceeds 3 mA or if the leakage voltage exceeds 60 V DC (according to EN 50122-1 or IEC 62128-1).	5.1.3.3. Fuel cell vehicle (b) On-board isolation resistance monitoring ... (Annex 5)
5. The driver's compartment	5.3. Functional safety
5.1. In the driver's compartment, there should not be any high voltage equipment accessible by the driver.	
5.2. As a minimum, the instrument panel shall include: Indicator of voltage in the contact system; Indicator of zero voltage in the contact system; Indicator of state of main automatic line voltage circuit breaker; Indicator of charge/discharge of the batteries; Indicator of body voltage or leakage current exceeding the limits specified in §4.2. above.	At least a momentary indication shall be given to the driver when the vehicle is in "active driving possible mode". However, this provision does not apply under conditions where an internal combustion engine provides directly or indirectly the vehicle's propulsion power. When leaving the vehicle, the driver shall be informed by a signal (e.g. optical or audible signal) if the vehicle is still in the active driving possible mode. The state of the drive direction control unit shall be identified to the driver.
/	If the on-board REESS can be externally charged by the user, vehicle movement by its own propulsion system shall be impossible as long as the connector of the external electric power supply is physically connected to the vehicle inlet. This requirement shall be demonstrated by using the connector specified by the car manufacturer.
/	5.4. Hydrogen emissions + 6. REESS