May 5, 2016

Working group on standardisation of battery-electric buses – use cases[1)] & requirements

Opportunity charging[2)] – Standardized interfaces

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DISCLAIMER: WHAT IS A USE CASE?
1) A use case is a general description of how the electric buses operate and what the sequence of activities is. The involved actors and their relationship to the system are explained. Electric buses and charging stations need to have common interfaces (mechanical, electrical, and communication interfaces) in order to operate properly. The use case described here includes only conductive opportunity charging (frequent and with high power). This excludes inductive charging. More information about the description of a use case can be found in Annex.

2) To standardise the interfaces of the charging infrastructure for buses (utility vehicles), the requirements for the system are described below from the point of view of the operators and manufacturers.
Opportunity charging utilizes the short breaks in bus operation (e.g. at bus stops or end of route break) for high power charging. A complete charge is achieved in couple of minutes. The charged energy is sufficient for the bus to drive to the next bus to or end of route, where the next opportunity charging takes place. The benefit of this method is having less battery capacity onboard the bus.

- Steps for conductive charging should follow the same sequence. However, there is a difference between operation of regular (bottom-up from bus to infrastructure) and inverted (top-down from infrastructure to bus) pantograph, and other available conductive systems.
- Important operational points are the total time taken between arrival at the charging station and initiation of charging, and the time taken between completion of the charging process and vehicle readiness to move off.

1. Designation and description of actors and functions involved, and terms used

Actors, actions, and functions

- Stopping place
  — Stopping place for (electric) buses, which have been provided with a charging station for the charging of the traction batteries or the energy storage unit of an electric bus. This could be the bus stop or other stopping place off-route, eg. near the end stop (pausing location).
- Charging station
  — A charging unit on the infrastructure side providing the energy for the vehicle.
- Charging point
  — Point/parking space at which the vehicle can be parked and at which there is a facility for charging from a charging station. One charging station can supply to multiple charging points, if charging connectors are available.
- Electric vehicle
  — Vehicle with an electric propulsion system. The energy for the propulsion is drawn from an energy storage unit. The electric vehicle is driven by authorised/trained staff.
- Driver
  — Person operating the vehicle during the commercial operation
- Passengers
  — Persons in the line-service bus or waiting at the platform
- Back-office system/ Disposition system
  — The bus operator system used for vehicle planning and receiving data from vehicles and chargers.
- Energy management/Power management/Electric utility
  — System for the monitoring and control/distribution of the energy available for the charging of electric buses. Detection of the energy consumption per charging point. Typically operated by infrastructure energy management/energy supplier.
- Fleet management system
  — A back end system for monitoring and possibly controlling all the buses. Typically operated by the bus operator. May be separate system from Disposition system.
- Bus fleet
  — A fleet contains many buses that are connected to same fleet management system, and are operated by the same operator.
- Fleet manager/traffic planner
  — Establishes how much time the bus can charge before it must continue its journey.

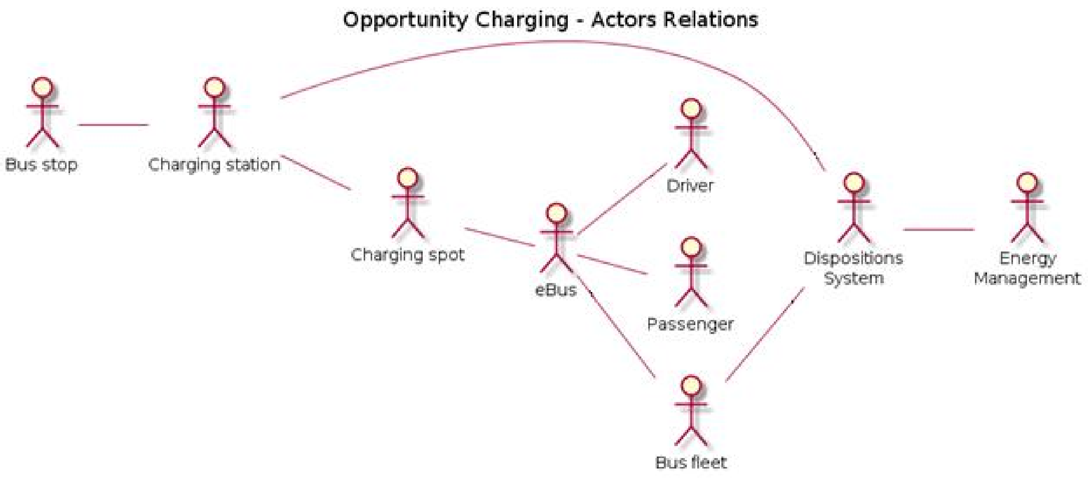


Figure 1 Actor/function relationship diagram of opportunity charging

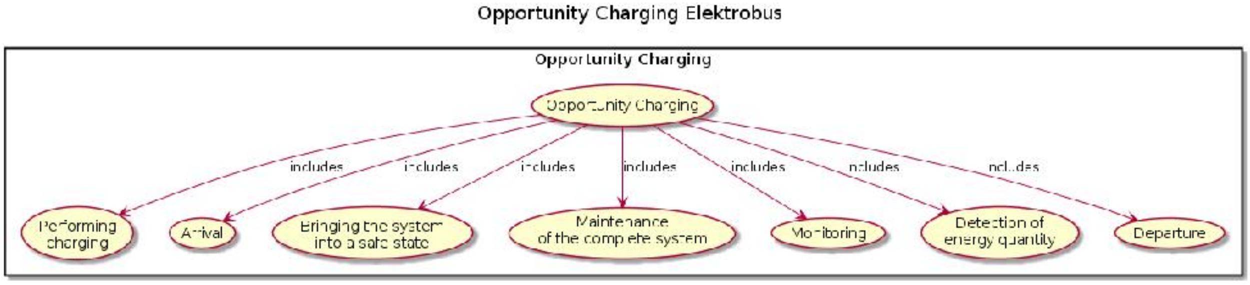


Figure 2 Use case diagram giving an overview of the concept of opportunity charging.

2. Presentation of the system and interfaces

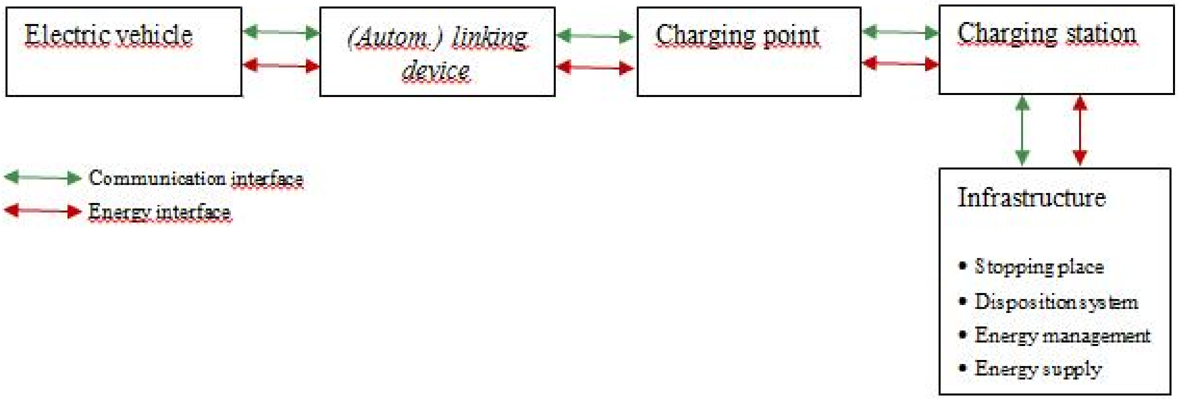


Figure 3 Diagram showing the system's different interfaces

Figure 3: The interfaces require compatible (standardised) communication and energy transfer interfaces. For energy transfer, the mechanical (junction; linking device in figure) and electrical (voltage and current) interfaces need to be compatible.

- Compability of electric circuits should be verified.

3. Sequence diagram and interaction diagram of opportunity charging

- The figures presented here aim to describe the process of opportunity charging and the use case of charging an electric bus. Actions are described step by step.

Note

The two activities “initiating charging” and “positioning vehicle” can be take place simultaneously.

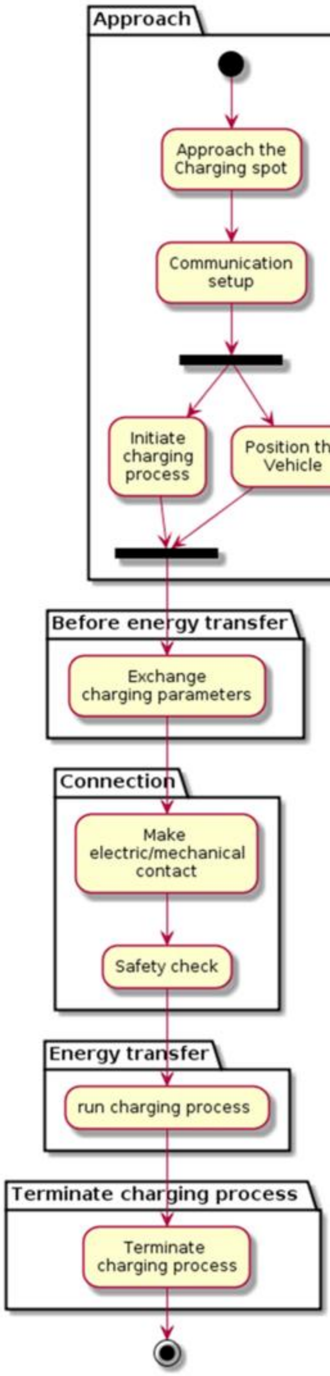


Figure 4 Process flow diagram

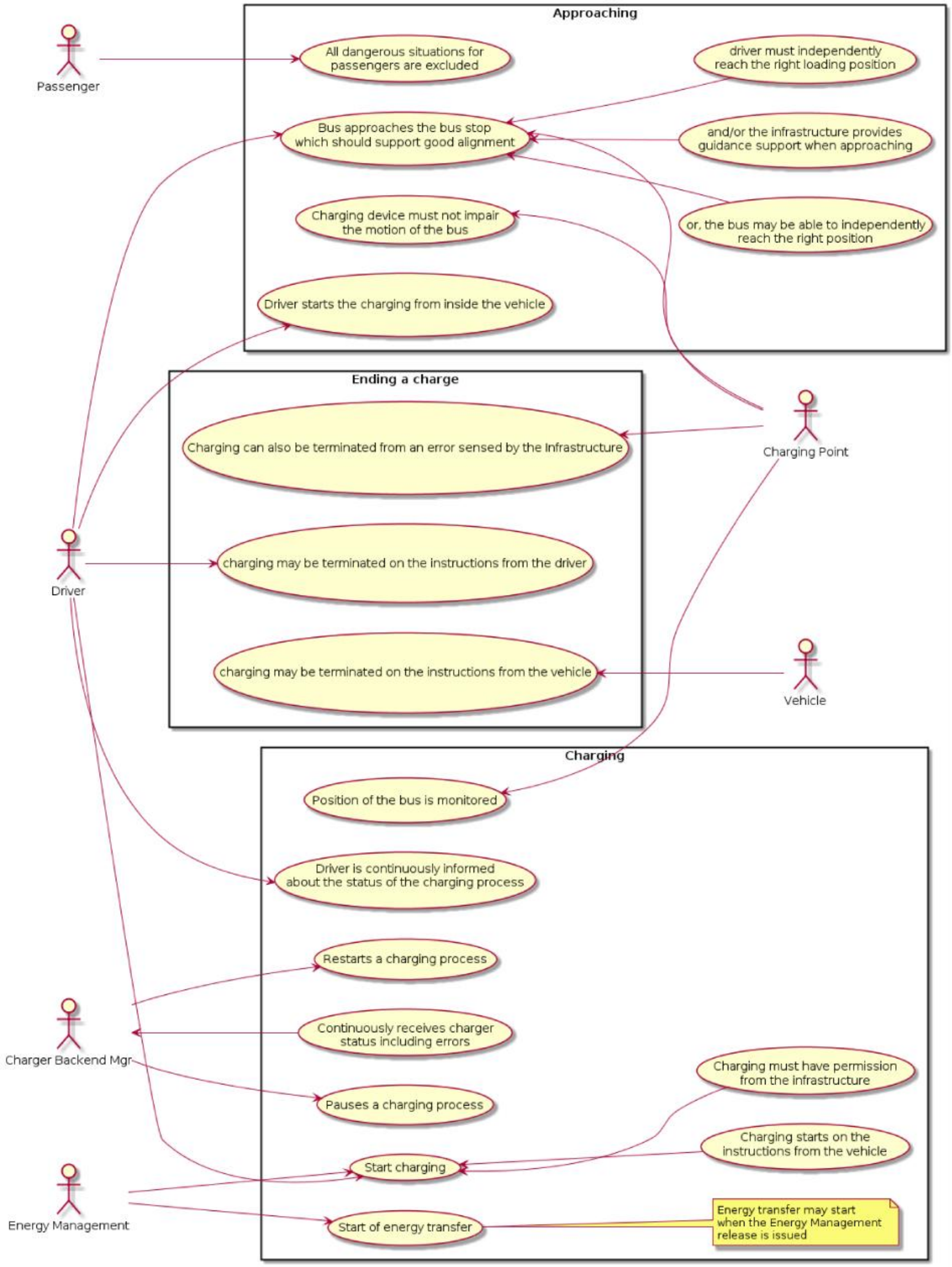


Figure 5 Interaction diagram of opportunity charging

	Functional requirements	Before charging		Preparation of energy transfer				Energy transfer		End of energy transfer			
		(vehicle speed > 0)				(vehicle speed = 0)						(vehicle speed > 0)	
		Vehicle	Ch. Point	Vehicle	Ch. Point	Vehicle	Ch. Point	Vehicle	Ch. Point	Vehicle	Ch. Point	Vehicle	Ch. Point
A	Insulation monitoring	X$^{1)}$	X$^{2)}$										
B	Charging point signalises readiness		X										
C	Charging point ready for charging detected	X											
D	Request message for charging			X									
E	Communication set-up			X									
F	Authentication			X	X								
G	Positioning / position detection and control			X	X								
H	Protection against unintended rolling					X$^{1)}$							
I	Provision of electromechanical contact					X	X						
J	Readiness for charging signaled					X$^{1)}$	X$^{2)}$						
K	Safety electric test						X		X$^{2)}$				
L	Transfer of energy							X	X				
M	Interruption of energy transfer							X	X				
N	Resumption of energy transfer							X	X				
O	End of energy transfer							X	X				
P	Disconnection of mechanical contact									X	X		
Q	Release for driving									X$^{1)}$	X		
R	Disconnection of communication connection											X	X

Figure 6 Sequence diagram of charging process.

X – Communication between vehicle and charging point (ch. point), 1) Test on the vehicle 2) Test on the charging point

Phases A-R describe the charging process. The charging process begins when a vehicle is approaching a designated charging point and ends when the communication is disconnected and the vehicle is leaving the charging point. Initiation of charging consists of steps D-K, because A-C are independent actions (do not require initiation of charging), and initiation is ready when the system is ready to transfer energy.

Requirements

- Maintenance: Interrogation of the system states and processing services.
- Both the vehicle and the charging system/point should have available interfaces, i.e. to be able to interrogate the respective states of the system (e.g. a FMS interface on the vehicle or any other system already available in the vehicle).
- At the end of the charging the energy quantities transferred from charger to vehicle and from grid to charger should be detected/interrogated by the charging system.
- Charging control is to be based on the standard ISO/IEC 15118.

4. Arrival of the electric bus and initiation of charging process

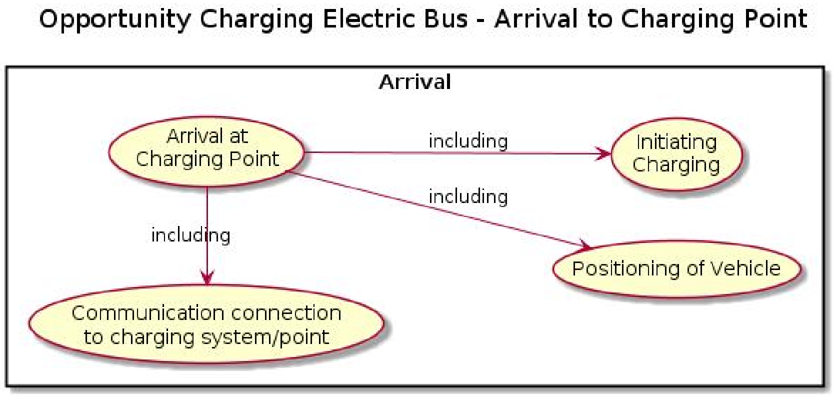


Figure 7 Use case of arrival of the electric bus.

- On arrival of the vehicle at the charging point, charging process can be initiated by the vehicle side before the energy transfer if all the preconditions are fulfilled (see e.g. VDV Recommendation 260, 2.1.3).
    - Manual positioning:
      the driver has to position the bus at the right place (e.g. by way of reference points fitted so that they can easily be seen by the driver or by an electronic guidance system).
    - Automatic positioning:
      the bus can automatically reach the correct charging position.
      Condition: The bus has been equipped with a suitable system (e.g. automatic park assist system).
- The vehicle is positioned according to user requirements, which might be country and vehicle specific.
- Initiation can begin before the protection against unintended rolling is applied; e.g. already on arrival.
- It should be possible to interrogate/detect the state of the charging point (ready/not ready) already when the bus is in the vicinity of the designated charging station. However, proximity should not be used as a requirement (to ensure that unauthorized charging cannot happen and that the charging point does not communicate with the wrong bus). The readiness of the charging point could be detected via centralized system (e.g FMS via OCPP).
    - Communication with the correct charging point has to be ensured if there are several charging points connected to a charging station.
    - Communication must be secured against reception or transmission by unauthorized third parties.
    - Communication with the correct charging point (charging point at which the vehicle is to be charged) has to be reliable/stable/clear during the entire charging process.
- The passengers shall never experience a hazard by single system fault.
    - Integrated level of safety (ASIL) should be determined.
- The charging process can be initiated automatically or by the driver.
    - Initiation of charging must be possible for the driver without leaving the driver’s compartment. In this case, the charging process should require human authorisation to commence charging.
        - The driver should not be required to remain with the vehicle throughout the charging process. During charging at the end of a route is a convenient opportunity for the driver to take a “comfort” break or to carry out driver changes.
- Valid VDV Recommendations/Reports and standards have to be observed (e.g. position of the pole, see VDV Recommendation 230/1, 8.5 and 18.5.2).
    - The contact system can be positioned already on arrival at a stopping place. However, the defined structure gauge always has to be observed (VDV Recommendation 260, 2.1.3 or other applicable).
- Only authorised vehicles may initiate charging. (Conflicts with current agreements / choices made in the car EVSE operators (CPO). In case of an error of both the “white list” and 4G connections, ALL vehicles CAN charge. This is a measure to reduce risk of technical failure on availability of charging.)

- The CPO could also optionally decline any connection during technical fault, because allowing all connections could cause misuse.

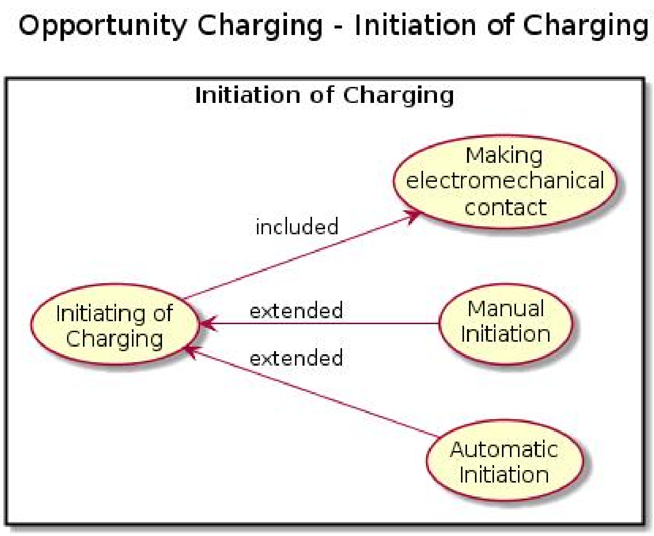


Figure 8 Initiation of charging.

- The minimum values of the structure gauge are observed; the electric vehicle, the charging point and the charging system fulfil all requirements for safe transfer of energy.
- When charging is initiated, the communication and the electromechanical contact between the charging infrastructure/point and the vehicle are set up
  - *Automatic charging initiation* – e.g. upon detection/authentication of the vehicle on arrival; a charging connection is automatically set up when the vehicle is parked and immobile on the charging point.
  - *Manual charging initiation* – the driver initiates charging when the vehicle is parked and immobile on the charging point. Part of the charging process can begin before the vehicle is immobile, e.g. communication and safety electric tests.
- The vehicle always has to be positioned correctly.
  - The given position tolerances have to be observed.
- The mechanical connection may only be set up when the vehicle has been correctly positioned and is protected against unintended rolling.
  - The position of the vehicle and the state of protection against unintended rolling have to be monitored during the whole charging process (excluding the phases when the vehicle is allowed to move).
- When the mechanical contact has been set up, the safety electrical test of the infrastructure is made for a contacted system; the current flow and the system monitoring can run in parallel.
- The maximum height of the vehicle can be up to 4.8 m, but it is mostly country, vehicle, and user-case specific.
  - Double decker busses should be included when defining the limit.
- Initiation is completed when the system is ready to transfer energy (e.g. contactors closed).
- A given order of contacting is to be observed (see EN 61851: The order of contacting has to be provided by an appropriate mechanical design of the contact system). The order of contacting is needed for systems with contacting and always has to be observed.
  - The following order is proposed for bus charging systems:
    - Voltage-free contacting
    - Safety electrical tests via closed PE contact/pilot circuit
    - Only when earthing has been tested successfully, may the power be connected.

5. Charging process

- The system has to be equipped with a robust communication connection based on a standard (ISO/IEC 15118) that has already established itself in the field of electric mobility.
- The driver is continuously informed about the state of the charging.
- The vehicle always has to be protected against unintended rolling during the charging.
    - The protection against unintended rolling has to be monitored during the charging.
    - The position of the vehicle may never change during the charging.
        - Kneeling could be allowed and the current collection system has to be balanced without interruption of the contact.

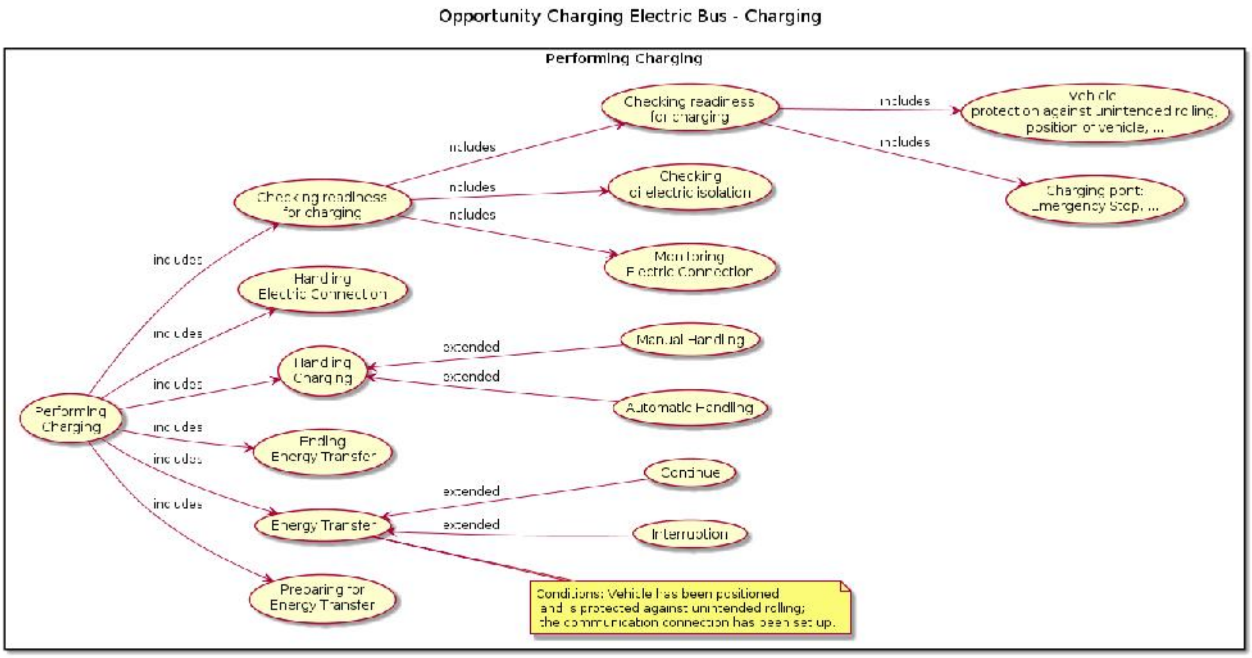


Figure 9 Use case of performing charging.

- Charging begins
    - Upon instruction given in the vehicle,
    - Upon the initiative of the infrastructure; applicable safety measures have to be observed.
- It has to possible for the driver to leave the vehicle when it is being charged.
    - It has to be allowed to draw the ignition key and lock the vehicle.
        - Passenger comfort systems can remain active.
        - Systems of relevance to the charging have to remain active.
- It has to be possible for the driver and passengers to board and alight from the vehicle during the charging.
    - ISO 6469-3 defines the safety specifications for EVs in order to ensure protection of persons inside and outside the vehicle against electric shocks.
- Charging follows CCS standard.
    - Allows interruption and continuation of charging.
- If there is a fault (caused by the vehicle or the infrastructure) or a power failure, the contacting system shall always fall back to its initial position/idle state.
    - Uninterruptible Power Source (UPS) should be allowed so that contacting system can be retracted. A mechanical mechanism is also an option ((VDV Recommendation 230/1, 18.5.2).
- During the connection between the vehicle and charger there shall be exchange of data as: charging current, voltage, and energy flow.

    - After successful charging process the vehicle and the power disconnection there should be two possibilities: fully charged vehicle or eventual repetition of the process. The decision between such two possibilities should be done manually or automatically.
- A possibility to reach and activate emergency stop should be present as part of the vehicle or infrastructure which has moving or otherwise dangerous parts.
    - An external button at the charging station that is secured from the public.

6. Requirements for monitoring of charging

- The energy transferred during charging is measured by the charging infrastructure and assigned to the vehicle and the charging period; this information is kept/recorded in an auditing-proof way.
    - The data is also used to invoice for the energy used.
- The energy quantity charged by an electric vehicle is recorded from the time of registration of the vehicle at the charging infrastructure.
    - Accuracy of the measured values to be detected is determined by electric utility.
    - Information about the energy quantity transferred to the vehicle should/can be passed on to the vehicle upon charging.
- Further data can be required in the specification (e.g. charging current curve, peak current, average current, voltage, etc.).
- If there is a fault within the charging system (vehicle, charging point, or charging system) during the transfer of energy, the ongoing charging is to be interrupted, indicated and recorded.
    - Fault situations should be defined and also the steps following the fault situations.
- Insulation resistance between ground and chassis should be monitored (IEC 61851-21 ch 7 and 8).
- Potential between conductor for returning current and ground should be 0V (no impedance) for the safety of passengers.

7. Requirements for completion of ongoing charging

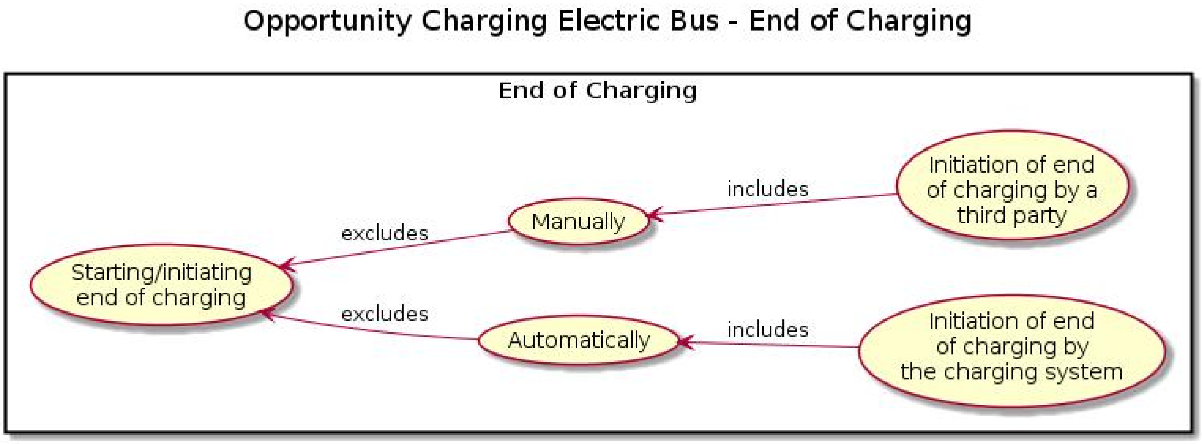


Figure 10 Use case of ending charging.

- Variant “automatic end of charging”: When the frequent-stop brake/parking brake (protection against unintended rolling) is deactivated, at the latest, the energy transfer is stopped and then the electromechanical charging connection between the charging infrastructure and the electric vehicle is disconnected; automatic end of charging can e.g. follow via a departure signal from the charging system connected with the ITCS.
- Variant “manual end of charging”: End of charging is initiated by the driver before he releases the frequent-stop brake/parking brake.

- It always has to be possible to stop ongoing charging
  - By the infrastructure,
  - By the vehicle,
  - Anytime,
  - Automatically or manually,
  - By actuating an emergency-stop button, which immediately initiates interruption of charging.
  - The ending of charging process normally follows CCS standard.
- The charging connection between the charging infrastructure and the electric vehicle has to be disconnected and brought into its initial position.
- The electric vehicle may only be moved when there is no contacting and no mechanical connection to the charging infrastructure.
  - The mechanical connection can only be removed once the contact is voltage-free.
- The driver can initiate end of charging before he releases the frequent-stop brake/parking brake.

8. Non-functional requirements and additional information

Note: As no use case motivates the non-functional requirements directly, at least one motivation is to be mentioned for the requirements.

When buses with energy storage units are to be operated, the operator and the manufacturer have to define the capacity of the battery. As batteries have a relatively low energy density compared to diesel, the capacity of the battery has a direct influence on the operating range, the passenger capacity and the operating concept.

When buses with “small” batteries, i.e. low-capacity batteries, as the main source of energy are recharged along their route (opportunity charging), there has to be an automatic high-power connection between the charging infrastructure and the vehicle.

- The charging infrastructure on the vehicle has to be so arranged in case of contacting on/over the roof that the pole is positioned in its centre longitudinal axis with a tolerance of ±25 cm to the middle of the front axle (longitudinal section of the vehicle).
- Usually, stopping places are only about 4 m longer than the bus types (12 m, 18 m or 24 m) scheduled for the route (i.e. there is 2 m space in front of the bus and 2 m behind the bus).
  - This is country-specific
- Much energy has to be quickly transferred to the vehicle by the charging infrastructure within the opportunity charging area. The interfaces needed for this purpose always have to be sufficiently robust and safe. The interface used for the transfer of the energy (electric (power) interface and the interface used for the control of the charging (communication interface based on ISO/IEC 15118) may never influence one another.
- The position of the contact system on the vehicle has to be so selected that the driver can easily position the vehicle at the charging station.
  - E.g. above front axle.
- The charging system has to be so positioned that a third party (e.g. a passenger) cannot get into contact with it during the charging.
- To achieve fast and barrier-free boarding and alighting (including handicapped passengers), no structural barriers shall obstruct the door areas of the vehicles at the stopping place. Care has to be taken that vehicles having different lengths and different door positions can stop at the same stopping place.
- To enable the procurement of electric buses (based on the opportunity charging concept), the interface between the vehicle and the infrastructure and the interface between the vehicle and the contact system have to be standardised to such a degree that it is easy to adapt / reconstruct them for operation in other cities. This creates competition between vendors and reduces costs.
  - A single mechanical connection standard is much preferred by operator and municipalities, rather than a proliferation of competing mechanical connection standards.
- For interoperability of buses and charging stations between different vendors, some baseline parameters for voltages should perhaps be defined.
  - Voltage limits are set in CCS standard
- Some basic parameters of the buses may need to be considered, for example minimum and maximum heights and widths of the bus.
  - Country-specific standards
- To dimension the system and define the space required on the vehicle, the tolerances for the mounting of the contact system within the infrastructure have to be defined. The standard EN 50122-1 can be applied for this purpose.
- The minimum height of live infrastructure cabling etc. is set by local regulations.

The standardisation should have the following objectives:

- Definition of the position of the charging system on the vehicle.
  - Above the front axle.
- Determination of the maximum space to be made available on the vehicle for electrical components.
- Determination of the position of the electric outlet on the vehicle and infrastructure.
- Determination of the positions of the mechanical fastening points on the vehicle.
- Clear definition of the area intended for contacting.
- To define the precise sequence of connecting, charging (CCS), disconnecting, and emergency conditions.
- Definition of the maximum noise generation at contacting and during charging
  - The noise generated during charging by exhaust fans etc. in the charging station should also be considered.
  - Noise measurement should be standardised.
  - The noise level should adhere to local requirements (transient and continuous).
- To define the minimum and maximum voltages that a bus may request from a charging station.
- To define minimum height above the road surface for any mechanical part of the charging station when not charging.
- To define a minimum and maximum height and width of vehicle that can be charged.
- Define safety protocols.
  - For example, the bus cannot move if the overhead charging station is not fully retracted. Also if there is a power failure, the overhead mechanism will automatically retract.
- To define basic security requirements for wireless communication.
- Observance of RASt 2006 for fittings in public places (minimum distance between bottom edge of charging infrastructure and upper edge of road: 4,500 mm).
- Charging should be possible for several companies (interoperability), incl. accounting of the energy charged:
- The standard should not make the operation of electric busses unviable, i.e. the standard should allow for fast operation, because it is one of the key aspects of opportunity charging.
- It is very important to have detailed description of HW and SW instruments, form and signification of the messages (as it is in term of CAN communication). Before the full compatibility of all system in the market will be finished, the fastest solution should be to start the identical solutions for the communication between the vehicle and the charger (one supplier, unique solution?). It leads us to the normalization of the communication interface:
  - Vehicle (drivers desk) – mobile equipment of the charger part on the vehicle (pantograph / contacts, and its control and security circuits.
  - Stationary communication node on the charger and on the vehicle(connection point).
    - Stationary communication node on the charger – control of the inverters (battery chargers) and the safety circuits of the charger.
- The tolerances for positioning listed below should be accepted or balanced by the system:
  - X axis: +/-500mm
  - Y axis: +/-250mm, max. 500 mm
  - Z axis: 2° (kneeling), tolerance angle at the X axis: 2°;
- Mechanical or technical guiding support can be used for the observance of the positioning tolerances.

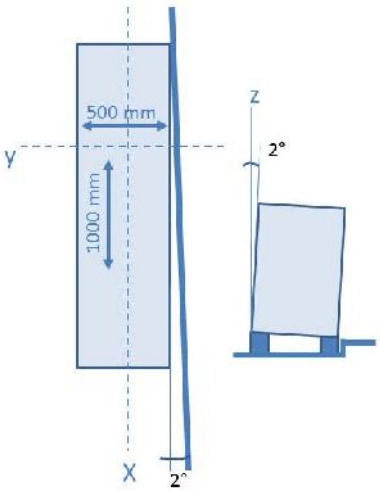


Figure 11 Positioning tolerances

A proposal for the positioning of a conductive overhead charging system

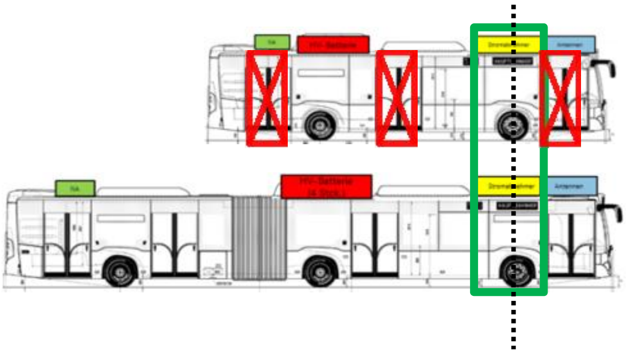


Figure 12 Proposal for the positioning of a conductive overhead charging system

- Longitudinal axis of the pole for the infrastructure components of a charging system with charging over/on the roof, tolerance ±25 cm

9. References

ECE R100	Approval of battery electric vehicles with regard to specific requirements for the construction, functional safety and hydrogen emission (emergency stop, battery isolation)
DIN SPEC 70121:2014-12	Electromobility - Digital communication between a d.c. EV charging station and an electric vehicle for control of DC charging in the Combined Charging System
VDV 230/1	Skeleton Recommendation on Urban Low-Floor Line-Service Buses Operated Electrically (Electric Bus)
VDV 260	Electric Bus – Infrastructure/Charging Points
RASt 2006	Directive for the design of urban roads (passage height)
EN 50122-1	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock (e.g. distances to be observed)
IEC 61557-8	Electrical safety in low voltage distribution systems up to 1000 V AC and 1500 V DC
IEC61508	Functional safety of electrical/electronic/programmable electronic safety-related systems
IEC 61140	
IEC 60529	
IEC 60364	
IEC 62040	
IEC 6469	
ISO 17409	
IEC IS 61850	
IEC 61851	
ISO/IEC 15118	
IEC 62196	

Annex

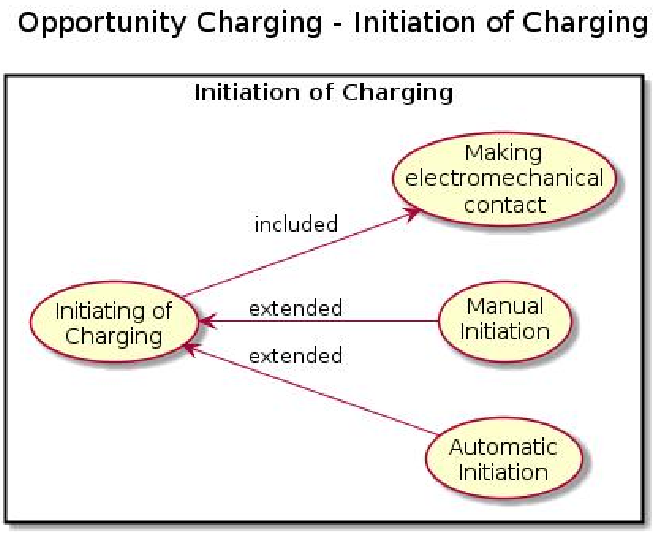
DISCLAIMER: WHAT IS A USE CASE?

Use cases are used to describe proposed functionalities of new systems, typically related to so called actors/stakeholders, the users of the proposed system. Actors can be a person, a system or organisation, a computer program or other system hardware outside a system to be developed.

The **methodology use case** can be used to identify and organize the requirements. A **use case** poses the functionalities shall be build into a proposed system that enables a user to achieve a goal. **Use case analysis** is the first and important step of requirement analysis widely used in modern software and system development today. They define the interactions between users and the system proposed. When models are used to **describe use cases**, each approach must define his project-specific interpretation. The really important point of **use cases** is to gather the user needs of the proposed system. **Use cases** can be in relation to each other and/or actors. To describe **use cases** in a more or less abstract way, the so called **UML Use Case diagram** can be used. These diagram are (hopefully) easy to understand and can be a good bases for discussions with users of the new system. Each **use case** itself is represented by a bubble, actors are shown by a stick man, e.g.

DISCLAIMER: UML USE CASE DIAGRAM

The relationship between actors and use cases are modelled by arrows normally named 'include' or 'extend'.



'included'	Use case “Initiating of Charging” (A) contains use case “Making electromechanical contact” (B) – whereby B is called every time the parent use case A is applied.
'extended'	Use case “Manual initiation” (C) extends the behaviour of use case “Initiating of Charging” (A) - C can be applied, but don’t have to, alternatively “Automatic Initiation” (D) could be applied instead of C.

Acknowledgements

Alexander Stucke (Iveco)
Ali Ugur (ABB)
Anders Folkensson (Scania)
Andreas Laske (Siemens)
Anton Mueller (Man)
Arno Kerkhof (UITP)
Bastian Mueller (Stadtwerke-Bonn)
Bernd-Peter Elgas (Evobus)
Bob Bouhuijs (Heliox)
Bogdan Kaczmarczyk (Solaris)
Bruce Warner (ABB)
Burak Onur (Temsa)
Christian Köbel (Bombardier)
Daan Nap (ABB)
Daniel Schneidecker (Translohr)
Dawid Kmiecik (Ekoenergetyka)
Dennis John (MAN)
Götz v. Esebeck (MAN)
Jens Gayko (VDE)
Moritz Vogel (VDE)
Eberhard Nickel (LVB)
Edward Jobson (Volvo)
Felix Von Pechmann (RATP)
Frank Ahrndt (ÜSTRA)
Frank Krämer (MAN)
Gert Miederna (ABB)
Hector Olabe (Irizar)
Hendryk Münster (Hochbahn)
Henning Franke (ABB)
Jakub Jerabek (Skoda)
Janusz Bosakirski (MZA Warsaw)
Jean-Luc Hourtane (Alstom)
Jens Schmitz (VDV)
Jeremie Desjardins (Bombardier)
Joerg Heuer (Siemens)
Johan Holmen (Volvo)
Johan Kaptein (ABB)
Josep Ariño (TMB)
Jörn Schwarze (KVB)
Kerstin Sann (DKE)
Lena Sundström (Volvo)

Marcel Hessel (Man)
Mark Poulton (TFL)
Markus Balke (Evobus)
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Michal Sierszynski (Solaris)
Mike Weston (TFL)
Niklas Petterson (Scania)
Paride Gasparini (CTM Cagliari)
Pavel Kuch (Skoda)
Peter Cremers (VDL)
Peter Hasler (KVB)
Philippe Grand (Iveco)
Philippe Veyrunes (Alstom)
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Roger Bedell (Opbrid)
Samu Kukkonen (VTT)
Simon Royal (TFL)
Stefan Baguette (Solaris)
Stefan Sahlmann (Man)
Teemu Raitaluoto (VTT)
Thomas Fabian (VDA)
Thomas Hartmann (Volvo)
Ulrika Juthage Gillenius (Volvo)
Umberto Guida (UITP)
Wilfried Weigel (Schunk)
Wolfgang Hubenthal (FFG (Hochbahn))
Wolfgang Presinger (Volvo)
Xavier Benoit (Adetel Group)
Yusuf Demirkaya (BSAG)