Siemens eBus charging infrastructure
Different charging principles and possible drive concepts

- Intercity Coaches
  - Touristic Traffic (~ 10,000 buses)
    - Diesel (also as hybrid)

- Regional Traffic (~ 12,000 buses)
  - Combustion engine
  - Electric drive
    - Gas (also hybrid)
    - Diesel (also hybrid)

- City Traffic (~ 20,000 buses)
  - Opportunity charging

- Non-scheduled Traffic
  - Overnight charging

- Diesel (also as hybrid)
  - Fuel Cell
Siemens eBus charging infrastructure
Opportunity & Overnight charging: Both seen as viable options for charging of electric buses

Charging for electric buses
According to VDV ¹)

Market / customers
Opportunity / overnight charging approach

- **No clear market tendency** towards ‘opportunity’ or ‘overnight / depot’ charging
- Customers expect to implement both charging approaches depending on specific ‘route’ and service requirements
- Challenges for both system will ‘materialize’ once electric bus systems are rolled out on a large scale (e.g. energy supply for bus depots; infrastructure in city centers)
- **Siemens offer solution for both**, opportunity & overnight charging for electric buses

Pro’s & Con’s opportunity vs. overnight charging

<table>
<thead>
<tr>
<th>Opportunity charging</th>
<th>Overnight / depot charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ Small battery size</td>
<td>+ Operational flexibility</td>
</tr>
<tr>
<td>+ Unlimited range</td>
<td>+ Easy to operate</td>
</tr>
<tr>
<td>- Infrastructure in cities</td>
<td>- Large battery size</td>
</tr>
<tr>
<td>- Operational flexibility</td>
<td>- Insufficient range</td>
</tr>
</tbody>
</table>
Siemens eBus charging infrastructure
Driving standardization and ensuring system ‘interoperability’ for our customers

Visit us on: www.ebuscs.net

Press release March 15 2016

Group of European electric bus manufacturers agrees on an open interface for charging

European bus manufacturers Irisbus, Solaris, VDL and Volvo have agreed to ensure the interoperability of electric buses with charging infrastructure provided by ABB, Heliox and Siemens. The objective is to ensure an open interface between electric buses and charging infrastructure and to facilitate the introduction of electric bus systems in European cities.

The public transport community in preparing for electric buses in Europe and standardization activities have started via the European body (CEN-CENELEC) and via the international organizations for standardization (ISO/IEC). European standards are expected to come in place 2019 and international standards in 2020.

However, many cities are implementing electric bus systems already now. In order to meet the needs of these cities, European bus manufacturers Irisbus, Solaris, VDL and Volvo have together with charging system suppliers ABB, Heliox and Siemens agreed on an open, transparent and voluntary approach. Common, preferred interfaces will be opened-up for all market participants and will be used for electric buses with so called opportunity charging (that charging at end stops) and for overnight charged electric buses. The group is committed to contribute to European standardization activities and to share experiences with CEN-CENELEC and ISO/IEC in order to establish a common European standard for electric bus systems.

The objective is to facilitate the transfer to electric bus systems in order to ensure reliability and comparability across bus brands and charging systems. Other bus manufacturers and charging system suppliers are invited to join the cooperation.

For opportunity charging, the system includes automatic connecting by a pantograph, wireless communication, connecting plates and infrastructure equipment that automatically connect vehicles with a pantograph. For overnight charged electric buses, the first charging standard for cars (CCS) will be used as a base for the electric bus.

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Siemens eBus charging infrastructure
World premiere: Siemens to prove interoperability of the charging system in Hamburg with Volvo & Solaris

World premiere in Hamburg

Interoperable Siemens infrastructure

- Fully interoperable Siemens charging system to deliver electric charge to Solaris and Volvo buses
- Siemens proves to customers that Siemens infrastructure can be easily integrated with different bus OEMs
- Siemens delivers strong evidence to its commitment to an open standard for electric bus charging
### Siemens eBus charging infrastructure

#### High Power Charging systems in operation

<table>
<thead>
<tr>
<th>High Power off-board charging</th>
<th>Passenger operation</th>
<th>Factory / test charger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hamburg</td>
<td>Volvo: Arendal / Hållered</td>
</tr>
<tr>
<td></td>
<td>Stockholm</td>
<td>Volvo: Wroclaw</td>
</tr>
<tr>
<td></td>
<td>Gothenburg</td>
<td>Nova Bus: Montreal</td>
</tr>
<tr>
<td></td>
<td>Montreal</td>
<td>Nova Bus: Altoona</td>
</tr>
<tr>
<td></td>
<td>Oslo (in execution)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>High Power on-board charging</th>
<th>Passenger operation</th>
<th>Depot chargers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vienna</td>
<td>Wright Bus</td>
</tr>
<tr>
<td></td>
<td>Regensburg (in execution)</td>
<td>Volvo / Renault trucks</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CCS depot chargers &amp; eCobus</th>
<th>Airport buses incl. chargers</th>
<th>Depot chargers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stuttgart</td>
<td>Wright Bus</td>
</tr>
<tr>
<td>1)</td>
<td>Geneva</td>
<td>Volvo / Renault trucks</td>
</tr>
</tbody>
</table>

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1) Siemens scope ‘eCobus’: ELFA drive, battery pack, depot charger
Siemens eBus charging infrastructure
eBus portfolio covers off- and on-board high power charging, vehicle control unit and depot chargers

**High Power Charger (off-board)**

*Scope of supply*
- Inverted off-board pantograph
- High Power Charger
- Mast, transformer, housing
- Installation & civil works

**High Power Charger (on-board)**

*Scope of supply*
- Roof mounted pantograph
- High Power Charger
- Catenary lines
- Installation & civil works

**Vehicle Control & Communication Unit**

*Scope of supply*
- comBox and antenna
- Roof rails and DC switch
- Vehicle integration

**Depot chargers & eCobus**

*Scope of supply*
- High Power Charger (cable plug-in)
- ELFA drive train
- Battery pack
### Siemens eBus charging infrastructure

#### Portfolio – eBus Charging Solutions

<table>
<thead>
<tr>
<th>Top-Down Pantograph</th>
<th>Charging @ catenary</th>
<th>Plug-in Systems Off-board</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power electronics off-board</td>
<td>Power electronics on-board</td>
<td>Off-Board Plug-In</td>
</tr>
<tr>
<td>Power levels 150, 300 and 450kW Grid connection AC 400V to 20kV</td>
<td>Power levels 60 and 120kW DC 750V via catenary Connection via Plug-in to AC 400V 63A</td>
<td>Power levels 30-120kW Grid Connection AC 400V</td>
</tr>
</tbody>
</table>

#### Plug-in systems On-Board

- On-Board charging devices with 7 or 14kW
- Grid Connection 230/400V AC
Siemens eBus charging infrastructure
“We accompany our customers and partners from the idea to the realization!”

System design & layout

On-board components & integration

Charging infrastructure

Project execution, installation & service
Siemens eBus charging infrastructure
Portfolio – eBus Charging Solutions

Top-Down Pantograph
Power electronics off-board
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph

- Grid Connection and switching devices
- Transformer
- High Power Core Charger and system controller
- Save enclosure for power electronics
- Mast and mast cover for pantograph
- Invers mounted pantograph
- WiFi communication between bus and charging station
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph

Fast, reliable, efficient
- Proven technology
- Dimensioned to customer’s requirements (e.g. driving schedule and energy consumption)
- Save weight on the vehicle for more passenger capacity
- Small battery packs on the vehicle to reduce weight and preventive maintenance costs for vehicles

Fully automated
- Easily activated from inside the vehicle by using known procedures
- Highest possible safety for drivers and passengers based on international standards

Scalable
- 1:n relationship of charger to vehicles (one charging station suits 5-10 buses per hour)

Flexible
- Charges multiple bus types
- Flexible to different grid requirements
Siemens eBus charging infrastructure
Hamburg: First Opportunity Charging System with inverted pantograph
(in operation since December 2014)
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph
“Hamburg project” overview

Customer: Hamburger Hochbahn AG

Innovation bus line 109 with a milage of 9 km

**Four charging points connected to a medium voltage (10 kV AC)**
- Two charging points connected to Metro grid
- Two charging points connected to local electricity provider
- Installed charging power per charging point of 300kW

**Siemens scope of delivery:**
- Two charging stations (ZOB and Alsterdorf) equipped with
  - 2x 300kW HPCC (High Power Core Charger)
  - 1x Low voltage distribution for light, electric heating and other low voltage facilities
  - 3x Transformer for HPCC and low voltage distribution
  - 1x Medium voltage with three outflows
- 4x Customer specific mast with top-down pantograph
- Sensors for positioning and safety features
- Erection, installation and commissioning
- Civil works and permits

**Additional information**
- 10-month project realization
- In public operation since december 2014
- Three plug-in hybrid buses from Volvo in operation
- Three full-electric buses from Solaris planned for M2016 for operation
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph
“Stockholm project” overview

Customer: Vattenfall Sweden

Busline 73 with a milage of 6.5 km
- Two charging points with low voltage power supply (400 V AC)
- Installed charging power per charging point of 150 kW

Siemens scope of delivery:
- Two charging points equipped with each
  - 1x 150kW HPCC (High Power Core Charger)
  - 1x Transformer for HPCC
  - 1x Low voltage power connexion
  - 2x Customer specific mast with top-down pantograph
  - 2x Pantograph cover
  - Sensors for positioning and safety features
  - Commissioning

Customer scope of delivery:
- Erection and installation
- Civil Works and permits

Additional information:
- 10-month project realization
- In public operation since March 2015
- Two plug-in hybrid buses from Volvo in operation
Siemens eBus charging infrastructure
Gothenburg: First indoor Opportunity Charging System
(in operation since June 2015)
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph
“Gothenburg project” overview

Customer: Göteborg Energi
Busline 55 with a milage of 9 km
- Two charging points with low voltage power supply (400VAC)
- One indoor and one outdoor charging point
- Installed charging power per charging point of 300kW

Siemens scope of delivery outdoor:
- 1x 300kW HPCC (High Power Core Charger)
- 1x Transformer for HPCC
- 1x Low voltage power connexion
- 1x Customer specific mast with top-down pantograph
- 1x Coverage of mast
- Sensors for positioning and safety features
- Erection, installation and commissioning
- Civil works

Siemens scope of delivery indoor:
- 1x 300kW HPCC (High Power Core Charger)
- 1x Transformer for HPCC
- 1x Low voltage power supply
- Pantograph with roof mounted installation
- Sensors for positioning and safety features
- Installation in local cellar, commissioning

Additional information
- 10-month project realization
- In public operation since June 2015
- Seven plug-in hybrid buses and three fully electric buses from Volvo in operation
Siemens eBus charging infrastructure
High Power Charging (HPC) - Off-board top-down pantograph
“Montreal project” overview

Customer: STM (Societe du Transport du Montreal) Montreal, Quebec, Canada

Busline 34 with a milage of 10 km

- Two charging points with low voltage power supply (600VAC)
- Installed charging power per charging point of 450 kW

Siemens scope of delivery:
- Two charging points equipped with each
  - 1x 450kW HPCC (High Power Core Charger)
  - 1x Transformer for HPCC
  - 1x Low voltage power connection
- 2x Customer specific mast with top-down pantograph
- 2x cover for mast and pantograph
- Sensors for positioning and safety features
- Erection and installation
- Commissioning

Additional information:
- 13-month project realization
- Public operation scheduled for March 2017
- Three full electric buses from Novabus in operation
Siemens eBus charging infrastructure
Portfolio – eBus Charging Solutions

Charging @ catenary
Power electronics on-board
Siemens eBus charging infrastructure
Charging via catenary – On-board bottom-up pantograph
“Vienna project” overview

Customer: Wiener Linien
Bus routes 2A and 3A – in public operation since October 2012
• 12 fully electric 8m-buses from Rampini (Italy) in commercial operation
• Two charging points in the city centre at end terminals
• One charging point in the depot – 2 x roof mounted rails for each serving 6 buses with grid connection to nearby metro grid
• Utilization of tram power supply
• Charging equipment on the roof of the bus incl. 2-pole-pantograph
• Charging power 60 kW

Siemens delivery scope
• 12x ELFA drives
• 12x DC-DC inverter 60 kW
• 12x „bottom-up“ pantographs (2-pole)
• Installation and commissioning
• Overall project management
• Civil works

Additional information
• Siemens in a consortium with Rampini
• 10-month project duration

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Siemens eBus charging infrastructure
Portfolio – eBus Charging Solutions

Plug-in Systems
Off-board
Siemens eBus charging infrastructure
Plug-in solutions with connector
“Stuttgart project” overview

Customer: Airport Stuttgart

Airport traffic solution

- 6 fully electric buses in commercial operation
- Charging power 60 kW

Siemens delivery scope
- Charging stations with plug-in connector (Combo2)

Additional information
- Public Operation since October 2015
- Besides several test operations within Europe (Airports e.g. Lisbon, Geneva, Vienna)
Siemens eBus charging infrastructure
Different charging principles are established in the market covered by Siemens eBus charging infrastructure portfolio

**HPC System**
- **150, 300 or 450kW**
  - **Infrastructure:** Charging power electronic, mast, contact system
  - **Bus:** Contact Rails and Communication interface (wireless)
  - **Grid connection:** different solutions possible (low, medium voltage)
  - **Preferred applications:** high density city traffic

**Charging via Pantograph to catenary**
- **60 or 120kW**
  - **Infrastructure:** 2-pole DC connection (750V DC e.g. from Tram)
  - **Bus:** DCDC inverter, pantograph
  - **Preferred applications:** medium density city traffic, operation with low numbers of buses (e.g. Island traffic)

**Overnight Charging (Plug-in)**
- **System:** DC Charging (CCS) - 30 up to 120kW
  - **Preferred applications:** Airport buses, Shuttle service, buses for peak operation, Test trials

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<table>
<thead>
<tr>
<th>Daily Mileage [km]</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
<th>200</th>
<th>250</th>
<th>300</th>
<th>350</th>
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<tbody>
<tr>
<td>1 - 6 min</td>
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<tr>
<td>6 - 10 min</td>
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<tr>
<td>2 to 6 hours</td>
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</tbody>
</table>

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<table>
<thead>
<tr>
<th>Charging procedures per day</th>
<th>1 - 15</th>
<th>15 - 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging time per day</td>
<td>1 - 5h</td>
<td>1 - 1,5h</td>
</tr>
</tbody>
</table>

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