Lima eBus Charging Infrastructure
Workshop Agenda

1. Global Differences Power & Electricity
2. Charging Standardization
   1. SAE Standards
   2. OppCharge
3. eBus Charging Technology
   1. Plug-in Charger
   2. Pantograph Charger
   3. Inductive Charging
4. Considerations for Charging Technology
   1. Peak vs. Off Peak Charging
   2. On-site Energy Storage
   3. Layout of Depot
   4. Power Requirements to Depot (Infrastructure Upgrades)
   5. On-Route vs. Depot Charging Summary
5. Overview of Lima eBus Charging
6. Session Wrap & Questions
eBus Charging Technology
Global Power Distribution Differences

- Electricity distribution differs by country (voltage, phase)
- Peru operates on 220 V, 60 Hz electrical system
Oppcharge

- Initiative aimed at establishing common interface and interoperability for electric vehicle charging

- **Key components:**
  - Connector Type
  - Vehicle/Charger Positioning
  - Communication Protocol
  - Performance

- Partnership of leading global eBus and charging infrastructure OEMs
OppCharge TransLink eBus Pilot

- TransLink partnership with CUTRIC to pilot eBuses from New Flyer and Nova Bus
- On-route charging stations from ABB and Siemens
- Launched September 2019

Key Drivers for OppCharge:
- Interoperability of eBuses and charging stations
- Reduce infrastructure costs
- Supply chain management for maintenance and repairs
Plug-in Charging Standard Connectors

<table>
<thead>
<tr>
<th>Wechselstrom (AC)</th>
<th>Typ 1 / USA</th>
<th>Typ 2 / Europa</th>
<th>GB / T / China</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE J1772 / IEC 62196-2</td>
<td>IEC 62196-2</td>
<td>GB/T 20234.2</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gleichstrom (DC)</th>
<th>Typ 1 / USA</th>
<th>Typ 2 / Europa</th>
<th>GB / T / China</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEC 62196-3</td>
<td>IEC 62196-3</td>
<td>GB/T 20234.3</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>„Combined AC/DC Charging System“</th>
<th>Typ 1 / USA</th>
<th>Typ 2 / Europa</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE J1772 / IEC 62196-3</td>
<td>IEC 62196-3</td>
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</table>

SAEJ1772 is to specify standards for the plug-in vehicle inlet and the mating connector in order to allow interoperability of plug-in vehicles at charging stations.
• Standard development organization, largest produced of automotive/ground based vehicle standards in the world

• Key standards for electric vehicle charging:
  • SAE 1772 Electric Vehicle Conductive Charge Coupler
  • SAE J3105 Interoperability of On Route Charging (Pantograph)
  • SAE J2954 On Route Inductive Charging Systems
  • SAE J2931 Charging Data Communication Protocol
eBus Charging Technology
**Charging Protocols and Connectors**

**AC** – Alternating Current
**DC** – Direct Current

AC – High Power Density rate of Transfer (used in electrical grid)
DC – Fast charge batteries

**Rectifier** – Converts AC to DC

**Diode** – Semi-conductor (allows current flow in one direction only)
Plug-in Charging Station

<table>
<thead>
<tr>
<th>Charging level</th>
<th>AC / DC</th>
<th>Power</th>
<th>km added per hour of charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>AC and DC</td>
<td>0-10 kW</td>
<td>50 km</td>
</tr>
<tr>
<td>Level 2</td>
<td>AC and DC</td>
<td>10-50 kW</td>
<td>50 – 250 km</td>
</tr>
<tr>
<td>Level 3 (Fast charging)</td>
<td>Only DC</td>
<td>&gt; 50 kW (up to 350 kW)</td>
<td>250 – 1750 km</td>
</tr>
</tbody>
</table>

- Charging connector plugged into vehicle charging port
- Need for manual connect/disconnect
- Charging port and connector differ based on country standards and AC vs. DC charging
- Typical method for depot charging
- DC Level 3 used for fast plug-in charging (up to 350 kW)
Sample Plug-in Charging Spec

New Flyer Xcelsior with Siemens Plug-in system

### Plug-in Charger Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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<tbody>
<tr>
<td>OEM</td>
<td>Siemens</td>
</tr>
<tr>
<td>Power Available</td>
<td>150 KW, 3-phase 480 VAC</td>
</tr>
<tr>
<td>Maximum Output Current</td>
<td>200 A</td>
</tr>
<tr>
<td>Voltage Supplied to Vehicle Receptacle</td>
<td>Regulated DC</td>
</tr>
<tr>
<td>Vehicle Receptacle Type</td>
<td>CCS Type 1, SAE J1772</td>
</tr>
<tr>
<td>SAE Standard</td>
<td>IP54</td>
</tr>
<tr>
<td>Enclosure</td>
<td>Included</td>
</tr>
<tr>
<td>Isolation Transformer</td>
<td>Button mounted on panel</td>
</tr>
<tr>
<td>Fault Monitoring</td>
<td>-35°C to +55°C (-31°F to 131°F)</td>
</tr>
<tr>
<td>Emergency Stop</td>
<td>Full UL and CSA certification</td>
</tr>
<tr>
<td>Operating Temp</td>
<td>7” color touch screen</td>
</tr>
<tr>
<td>Certification</td>
<td>Pre-programmed to CCS Type 1 or CCS Type 2</td>
</tr>
<tr>
<td>Certification</td>
<td></td>
</tr>
<tr>
<td>User Interface</td>
<td></td>
</tr>
<tr>
<td>Charge Controller</td>
<td></td>
</tr>
</tbody>
</table>

### Plug-in Charging Times

<table>
<thead>
<tr>
<th>ESS kWh</th>
<th>Time to Charge from 10% to 90% SOC (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>48</td>
</tr>
<tr>
<td>150</td>
<td>72</td>
</tr>
<tr>
<td>200</td>
<td>96</td>
</tr>
<tr>
<td>320</td>
<td>173</td>
</tr>
<tr>
<td>400</td>
<td>216</td>
</tr>
<tr>
<td>480</td>
<td>259</td>
</tr>
</tbody>
</table>
Overhead Charging Station

- Automated pantograph charger connected to High Voltage source contacts charging rails
  1. **Top Down:** Pantograph mounted to charging station
  2. **Bottom Up:** Pantograph mounted to eBus

- Wireless position sensors detect when eBus is located under charging station
- High power transfer rate up to 600 kW
- Charge during layovers at route terminals and end points (typical charge time 4 to 6 mins)
Sample On-route Charging Spec

New Flyer Xcelsior with Siemens OppCharge System
Inductive Charging

- WAVE (Wireless Advanced Vehicle Electrification)
- Power transfer rates of 50 kW and 250 kW
- Electromagnetic field delivers charge from primary coils to secondary coils mounted to eBus
- Automated charging process with wireless position sensors
  - Inefficient power transfer
  - High capital cost
- Vineyard Transit Authority (VTA) regional transit in Massachusetts piloting BYD eBuses with WAVE
- Pilot BYD eBus Fleet 10 buses:
  - 30ft K7 (196 kWh)
  - 35ft K9S (350 kWh)
Considerations for Charging Technology
**On-Route vs. Depot Charging**

**Scenario 1:** No on-route charging (depot only)

- **Peak Demand:** 14 MW
- Narrow band of active charging
- Large portion of fleet charging at depot once block/route assignment is complete

**Peak Demand:** 14 MW
On-Route vs. Depot Charging

Scenario 2: Addition of On-route Chargers

- **Peak Demand:** 9.1 MW
- Fleet charging demand distributed across day
- Less number of buses charging at any one time thus reducing peak demand
On-Site Energy Storage

Peak Shaving:
- Reduce energy purchased from utility provider during peak demand hours
- Use on-site energy storage to charge industrial battery packs
- Supply energy during peak demand in order to reduce power draw on electrical infrastructure

Electricity rates ($/kWh) differ by time of day
On-Site Energy Storage

Objectives:
- Peak shave energy demand
- Supplement off-peak eBus charging
- Reduce electricity costs
- Serve as a backup power supply
Depot Charging Impact

Garage layout
- Bus parking laneways width to accommodate charging stations
- Roof and overhead door clearance for eBus height, access to roof mounted batteries

On-site power infrastructure
- Upgrade on-site High Voltage transformer
- Distribution of utilities to site
- Ducting of electrical cables in facility to charging stations
Considerations for On-route vs. Depot Charging

Advantages of On-Route vs. Depot Charging:

1. Disperse fleet charging load across a larger network reducing peak power demand at depot

2. Faster charging rates

3. Extend eBus range of operation without the need to return to depot

4. eBus with smaller battery sizes can be used to complete routes benefiting:
   1. Lower vehicle weight
   2. Increased passenger capacity
   3. Reduced impact to road surface condition
Considerations for On-route vs. Depot Charging

Disadvantages of On-Route vs. Depot Charging:

1. Need for on-route charging may become obsolete as battery technology and range improve

2. High capital cost of on-route charging stations (~ $1M)
   1. Higher degree of planning and stakeholder involvement (i.e. land use, coordination of utilities to site)
   2. High Voltage power infrastructure to multiple locations

3. Need to consider route interlining (i.e. multiple eBuses use a single charger location)

4. More difficult site access and higher service disruption to conduct charger maintenance

5. Fast charge can accelerate battery degradation

6. Higher risk of vandalism to equipment
Lima eBus Charging Infrastructure
Lima eBus Charging Infrastructure Overview
Thank you!

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