Electrification in the Transportation Industry
Stephanie Medeiros
Electrification in the Transportation Industry

Overview

- Electric Transportation Introduction
- Electric bus overview - Types of Electric Bus Technologies and types of charging
- Future trends for electric buses
- Going Electric – Where to start
- Grid impacts and Solutions
- Electric School bus offering
Electric Transportation Introduction
Why Electric Transport is Important for the Future of the World?

- CO$_2$ levels at an all time high
- Rising global temperature
- Over 53,000 deaths in the US alone from auto emissions
- Over 25% of emissions in Canada are transport related

Source: climate.nasa.gov
Global estimates of Bus fleet size are over 3 million units in operation around the world in 2017.

Currently, the #1 propulsion is Diesel, followed by CNG.

Electric Bus Technology has made huge advancements in the past decade.

Electric Bus Pilots are underway in every corner of the world.

- 18% electrified bus fleet in China.
- 385k electric buses globally.
Electric Transportation Introduction

School Bus Market in North America

- About 500,000 school buses in Canada and the US
  - 90%-95% diesel
  - Propane is most popular alternate fuel
- Multiple pilot projects for electric school buses in Canada and the US
- Less than 100 electric school buses in operation
- Majority in California
Electric Transportation Introduction

Why Battery Electric School Buses

- Great Performance
- Zero Emission: 70% cleaner than a diesel vehicle
- Cost effective: reduce the fueling and maintenance costs of a vehicle by over 40%
- Quieter
- Sufficient time to charge in between routes
- Vehicles start and end their routes at the same charging point / transportation facility
- Opportunity to educate the future generations on sustainable energy
- Planned charging times (smart off peak charging)
- kWh cost is constant and more predictable than alternative fossil fuel costs
Electric Bus Overview

Types of Electric Bus Technologies

Hybrid Electric Bus
- Low reduction in emissions
+ Lower capital costs (bus and infrastructure)
- Higher O&M costs

Fuel Cell Electric Bus
+ Low emissions
- High infrastructure costs
  limited availability
- Very high bus costs
- Very high O&M costs

Battery Electric Bus
+ No emissions
+ Reduced O&M costs
- High capital costs (bus and infrastructure)
- Less range (without enroute charging)
Electric Bus Overview
Types of battery charging – car example

**Charging out of reg. service**
from 8 to 16 hours

- AC Charging
  - Level I: 120 V
  - Level II: 240 V
  - On-board Charger
  - BMS
  - Li-ion battery

**Charging in service**
From 30 minutes to 1 Hour

- DC Charging
  - Level III+: 480 V
  - DC Fast Charging Station

Customer expecting home charging in 8-10 hours

Customer expecting minutes, not hours to charge
Electric Bus Overview

Electrification of buses vs cars

Meaning, **10 times the power** required to maintain comparable charging time.
Electric Bus Overview

### Charging out of reg. service (in depot)
- AC or DC chargers
- 10 KW–150KW

### Charging in service (terminal or “on route”)
- DC chargers
- 150KW – 450kW

Customer expecting 5 to 8 hours
- Battery Management System (BMS)
- Li-ion battery

Customer expecting minutes at terminal, seconds in route

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May 12, 2018
| Slide 10
Electric Bus Overview

Different types of battery charging

- Overhead wires / trolley
- On Route Charging
- Overnight DC Charging
- Overnight Inductive Charging
- Overnight AC Charging

Capacity of batteries
Infrastructure Cost
## Electric Bus Overview – Importance of Standards

Hardware and communications

<table>
<thead>
<tr>
<th>SAE J1772 AC</th>
<th>CHAdeMO</th>
<th>CCS (SAE Combo)</th>
</tr>
</thead>
<tbody>
<tr>
<td>240VAC; &lt; 19.2 kW</td>
<td>DC; &lt; 62.5 kW</td>
<td>DC; &lt; 90 kW</td>
</tr>
<tr>
<td>Typical 3.3, 6.6, 7.2 kW</td>
<td>20-50 kW, HP?</td>
<td>20-50 kW, 150-350 kW</td>
</tr>
</tbody>
</table>

* Indicates adaptor is available to enable open standards charging
Importance of Standards

CCS standard changes required for power >150 kW

<table>
<thead>
<tr>
<th>Standard</th>
<th>Specification (previous)</th>
<th>Max charging power for EV car</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHAdeMO</td>
<td>50-500V, 125A</td>
<td>~50 kW</td>
</tr>
<tr>
<td>CCS</td>
<td>200-500V, 200A</td>
<td>~95 kW</td>
</tr>
</tbody>
</table>

New high power CCS

Special CCS connector, backward compatible with today’s vehicles

- Up to 920 V<sub>dc</sub>
- 350 / 500 A<sub>dc</sub>
- 160 kW – 350 kW charging power

Power electronics cabinet parameters under review:
- Current
- Voltage
- Safety concept
- Isolation concept
- Electro Magnetic Compatibility (EMC)
- Power quality
- Accuracy
Electric Bus Overview - Future Trends of Electric Buses

Battery improvements – driven by the car industry

- **Cost reduction** allowing a better market penetration
- Energy density improvement allowing now to answer customer needs for range by increasing battery capacity for same vehicle efficiency
- Tipping Point for EV adoption $100/kWh (est. 2025) electric buses reach unsubsidized upfront cost parity with diesel bus

![BNEF lithium-ion Battery Price Survey (2010 - 2016)](image)
Future is higher range & higher charge power

CCS high-power (≥300 kW)}

DC high-power charging
CCS high-power (≥150 kW)

AC charging
(43 kW)

AC charging
(22 kW)

AC charging
(11 kW)

On the roads

2016  2017  2018  2019, 2020, ...

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Going Electric – Where to start

- Involve Electric utility: explore impact of electrification of bus fleet with utility
- Engage key stakeholders: school administrative and finance staff, transportation and facility departments including drivers and mechanics, and parents
- Find funding: Incentives and funding available for clean transport
- Explore charging options for your needs
- Engage drivers and mechanics to ensure proper support and training is in place
Factors in Selecting Battery Charging

Operation is the key factor for selecting the right technology

- Time at depot
- Number of runs
- Route topology and length
- Fleet size
- Common interface standard product
- Power demand impact
- Capital cost versus total cost of ownership
- etc.
Utility bills consist of energy charges and demand charges.

- Energy charges is the energy used kWh.
- Demand charge a fee based on the rate of which electricity is consumed (on a 15 minute interval) and is in kW.

**Impact of power demand charge: What is demand charge**
## Electrification of bus fleets: Grid Impacts and Solutions

### Impact of power demand charge

<table>
<thead>
<tr>
<th>Customer A</th>
<th>Customer B</th>
</tr>
</thead>
<tbody>
<tr>
<td>50kW load for 50 hours:</td>
<td>5kW load for 500 hours:</td>
</tr>
</tbody>
</table>

#### Usage

<table>
<thead>
<tr>
<th>Energy</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>$50kW \times 50 \text{ hours}$ = $2,500\text{kWh}$</td>
<td>$50kW$</td>
</tr>
<tr>
<td>$5kW \times 500 \text{ hours}$ = $2,500\text{kWh}$</td>
<td>$5kW$</td>
</tr>
</tbody>
</table>

#### Bill

<table>
<thead>
<tr>
<th>Energy</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2,500\text{kWh} \times 0.15 = $375$</td>
<td>$50kW \times 10.00 = $500$</td>
</tr>
<tr>
<td>$2,500\text{kWh} \times 0.15 = $375$</td>
<td>$5kW \times 10.00 = $50$</td>
</tr>
</tbody>
</table>

Total = $875

Total = $425
Electrification of bus fleets: Grid Impacts and Solutions

Impact of power demand charge

- Energy charges are associated with the costs of \textit{generating} electricity
- Demand charges are associated with the \textit{distribution} of electricity
- The challenge is to manage adequately the power demand which may result in costs to \textit{improved existing infrastructure}
- For the consumer, decreasing the peak demand will decrease demand charges
Solutions to grid impacts: Smart charging

Control charging of buses:
- Rates from utility
- Bus schedule
- Limit maximum power

Fleet Operation
- Fleet management
- Performance reporting
- System integration

Charger Management
- Hardware and software checks
- Charge(r) remote support
- Charge(r) maintenance

Connected Services
Solutions to grid impacts: Battery Energy Storage

Peak Shaving with Battery Energy Storage

Description
– Peak shaving stores power during periods of light loading on the system and delivers it during periods of high demand for the purpose of reducing peak demand for the electricity consumer.

Response time
– Short duration application that requires ability for fast discharging (generally measured in minutes).

Benefit
– Customers can save on their utility bills by reducing peak demand charges.
– Utilities can reduce the operational costs meeting peak demand.

[Diagram of energy storage and discharge cycles]
## Electric School Buses

<table>
<thead>
<tr>
<th>Name</th>
<th>Charging*</th>
<th>In production</th>
<th>Range (km)</th>
<th>Battery Size (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autobus Lion <em>Serie C</em></td>
<td>J1772 charging</td>
<td>2016</td>
<td>100 to 250</td>
<td>88 to 220</td>
</tr>
<tr>
<td>Blue Bird <em>All American RE Vision</em></td>
<td>J1772 charging</td>
<td>2018</td>
<td>160</td>
<td>150</td>
</tr>
<tr>
<td>Daimler (Thomas Built Buses) <em>Saf-T-Liner® C2 Jouley</em></td>
<td>J1772 charging</td>
<td>2019</td>
<td>160</td>
<td>100 to 160</td>
</tr>
<tr>
<td>Green Power Bus <em>Synapse 72</em></td>
<td>J1772 charging</td>
<td>2017</td>
<td>120 to 225</td>
<td>100 to 200</td>
</tr>
<tr>
<td>Volkswagen &amp; Navistar (IC) <em>ChargE</em></td>
<td>J1772 charging</td>
<td>2019</td>
<td>~200</td>
<td>TBD</td>
</tr>
<tr>
<td>Motiv Power Bus <em>EPIC</em></td>
<td>J1772 charging</td>
<td>2018</td>
<td>144</td>
<td>127</td>
</tr>
</tbody>
</table>

*DC charging offered as an option*
Conclusion

- School bus industry great potential for progress and innovation growth
- Involve key stakeholders from the start of electrification project
- Look for funding availability
- Do not underestimate power demand charges and explore the right mix of solutions for your reality
Questions and Contact Information

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