Integrating electric road vehicles with public transport electrical infrastructure in London

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London Context

- Fast growing city
- Air quality
- Political will
- EV uptake
- Electricity demand and distribution
Electrifying London Bus Routes

- Overnight or opportunity charging
- Operational schedules
- 675 routes, >9000 buses, ~90 garages, annually almost 0.5Bn km travelled and 2Bn passenger journeys served
TfL electricity infrastructure

- London Underground (LU) Electricity Grid
  - Major AC and DC electricity grid across the city
  - Sometimes deeply buried
  - Demand constrains from underground operations
  - Operating rules
Using the LU AC Grid for EV Charging

• Complex interplay of supply and demand

• High reliability and redundancy but dirty power

• Very tightly constrained operating rules

• Cost of groundworks

• Proof of concept
Validating the connection

- Ensure no detrimental effects on grid reliability
- Ensure charge points will operate from LU grid
- 6 7kW charge points
- Stepped approach to acceptance testing
- Vehicles integrated into regular fleet operations
Case Study: Route 74 Baker St to Putney Exchange

<table>
<thead>
<tr>
<th>Route</th>
<th>Day PVR</th>
<th>Night PVR</th>
<th>Route Length</th>
<th>No. passengers (Usage year 2015/16)</th>
<th>Bus Km Operated year 2015/16</th>
<th>Garage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mon-Fri</td>
<td>Sat</td>
<td>Sun</td>
<td>Mon-Fri</td>
<td>Sat-Sun</td>
<td>miles</td>
</tr>
<tr>
<td>74 / N74</td>
<td>21</td>
<td>21</td>
<td>16</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

**Frequencies (buses per hour)**

<table>
<thead>
<tr>
<th>Am Peak</th>
<th>Monday-Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>Am normal</td>
<td>Pm Peak</td>
<td>Pm normal</td>
<td>Early Am</td>
</tr>
<tr>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>6</td>
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</table>
Case study: Bus parameter

- 25 Buses
  - Putney garage
- 19 buses operate during the day
- 3 Day / Night
- 3 as night buses.

- Individual buses run between 45km and 202km/day (2 to 9 round trips.)
- Based on current technology electric buses would consume between 68 and 304 KWh/day
- As batteries age not able to cover the duty cycle from overnight
Case Study: Degraded battery

- 16% Degradation in capacity assumed
- 10 Buses can run several days on 1 depot based full charge.
- 13 min dwell time at far end of route
- 8 min charge via 300KW pantograph system.
- Adding in power requirements for heating increases the number of end of route charges.

<table>
<thead>
<tr>
<th>BUS No</th>
<th>% Battery Consumed (Only overnight charging)</th>
<th>% Battery Consumed if charged once at Baker Street</th>
<th>% Battery Consumed if charged twice at Baker Street</th>
</tr>
</thead>
<tbody>
<tr>
<td>159</td>
<td>75</td>
<td>60.6</td>
<td>45.7</td>
</tr>
<tr>
<td>160</td>
<td>75</td>
<td>60.6</td>
<td>45.7</td>
</tr>
<tr>
<td>151</td>
<td>82</td>
<td>66.8</td>
<td>52.0</td>
</tr>
<tr>
<td>153</td>
<td>88</td>
<td>73.1</td>
<td>58.2</td>
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<tr>
<td>158</td>
<td>88</td>
<td>73.1</td>
<td>58.2</td>
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<tr>
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<td>73.1</td>
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<tr>
<td>171</td>
<td>94</td>
<td>79.4</td>
<td>64.5</td>
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<td>79.4</td>
<td>64.5</td>
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<tr>
<td>155</td>
<td>107</td>
<td>92.0</td>
<td>77.1</td>
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<tr>
<td>162</td>
<td>113</td>
<td>98.3</td>
<td>83.4</td>
</tr>
</tbody>
</table>
Case Study: Environmental Impacts

- **CO₂ reductions**
  - 2.35 Tons/day
  - 844 Tons/year

- **Nox reductions**
  - 50.3 kg/day
  - 18 Tons/year

- **PM reductions**
  - 91.2 g/day
  - 32.8 kg/year

- **FC reductions**
  - 1761.3 L/day
  - 634079 L/year
Conclusions

• The LU AC grid can in some cases supply power for both TfL fleet vehicles and buses cost effectively.

• Geographic and electricity grid factors are site specific.

• Larger trial needed to fully validate this alternate use of the LU grid.

• Heating has a major impact on electrical power requirements.

• Combination of overnight charging and on route top ups needed in some circumstances.
Future rollout

- The London bus fleet
- TfL Estate
- London Boroughs of Hounslow and Haringey and the Cross River Partnership including the boroughs of Camden, Islington, Lambeth, Lewisham and Southwark
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