Implementing recharging inductive technology on heavy duty pavement bringing unlimited autonomy to electrical vehicles

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Roads of the Future

RELEVANT AXES

TECHNICAL SOLUTIONS

- Energy Exchange Infra./Vehicle/Network Mgmt
- Environmentally friendly / recyclable mat.
- Automated / self-diagnosed / self repair
- Communication
- Environmentally adaptable

PUBLIC TRANSPORT DEVELOPMENT

- e-mobility new standard
- Sustainable and Economically feasible
- Concepts adapted to urban env.
Technical Solution

**PAVEMENT RECHARGING VEHICLES ENERGY**

1. Inductive system: Initial Concept and challenges
2. Solution developed for Inductive charging at bus stops
3. Testing prototypes with the Full Scale Test at IFSTTAR
4. Improvements based on the full scale test

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**Concept and Challenges**

- **Iron core**
- **Primary and secondary windings**
- **Iron core can be split**
  - Air gap between primary and secondary winding possible
- **Primary side can be modified**
  - Primary winding around iron core can be replaced by several cables

How to implement the primary coil in the pavement?
Concept: Inductive recharge at bus stops

Requirements
- Very Restrictive Tolerances
- Complex cable geometry
- Large amount of components
- Metallic objects forbidden
- Pavement function and adaptable to variable geometries

Engineering developed solutions
- Production in factory environment / Prefabricated element
- Optimized cables support design (material, process, minimal vol.)
- Concrete mixture adapted
- Optimized reinforcement position
- Optimized holders
- GFRP bars and dowels, plastic used when possible

Pavement and Infrastructure Integration Challenges
Infrastructure integration

1. Prefabricated Road slab
2. Matching Network Chamber
3. Wayside Civil Enclosure
4. Cooling Unit

Full-scale test of first prototypes

APT Facility at IFSTTAR – Nantes, France

• Moving load in fatigue configuration: dual-wheel 65 kN
• Speed: up to 100 km/h (15 rounds/min.)
• Loading rate: up to 50 000 cycles/day
Testing configurations

First test on prototypes / 500,000 cycles 6.5 Tons on the wheel

<table>
<thead>
<tr>
<th>Slab</th>
<th>Dimensions [m]</th>
<th>Loading position</th>
<th>Thickness of concrete cover [cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5 x 2.4 x 0.25</td>
<td>middle</td>
<td>5.0</td>
</tr>
<tr>
<td>B</td>
<td>5 x 2.4 x 0.25</td>
<td>border</td>
<td>5.0</td>
</tr>
<tr>
<td>C</td>
<td>5 x 2.2 x 0.25</td>
<td>middle</td>
<td>4.0</td>
</tr>
<tr>
<td>D</td>
<td>5 x 1.25 x 0.25</td>
<td>middle</td>
<td>3.5</td>
</tr>
<tr>
<td>E</td>
<td>5 x 1.25 x 0.25</td>
<td>border</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Constructions of the test track
Testing configurations

Second test on final **PRIMOVE** Prefabricated Slab
1.000.000 cycles 6.5 Tons on the wheel

Improvements and Validation

**First test**
- Adjustment / calibration of the construction method for **semi-prefabricated concrete pavement**
- Achievement of integration of inductive system in the pavement
- Good results for durability test after 500.000 cycles
- FEM and test used to develop final generation

**Second test**
- Good results for durability test after 1.000.000 cycles
- Concrete mixture optimized \( D_{max} \) optimized
- Self-leveling concrete controlled for road environment
- Curing procedure improved
- Additional transversal bars in top cover
- Additional longitudinal bars in top cover
- Geometry adapted for standard product
- Special procedure for producing surface texture
Public Transport Development

**OPPORTUNITY CHARGING FOR BUS TRANSPORTATION**

1. Electric buses limitations and opportunity charging
2. Three cities having **Primove** installed
3. A system **communicating** permanently
4. **Dynamic charging**: tests **looking forward for the future**

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**Primove New Energy Bus**

Optimized opportunity charging versus classic E-bus

<table>
<thead>
<tr>
<th></th>
<th><strong>Classic E-Bus</strong></th>
<th><strong>Primove E-Bus</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery Size</td>
<td>(&gt;300 kWh)</td>
<td>(60 kWh)</td>
</tr>
<tr>
<td>Battery Weight</td>
<td>~3600 kg</td>
<td>720 kg</td>
</tr>
<tr>
<td>Passenger Capacity</td>
<td>~4500 kg = 75 Passengers</td>
<td>Passenger capacity same as Diesel Bus ~6000 kg = 100 Passengers</td>
</tr>
<tr>
<td>Battery Lifetime</td>
<td>2-3 years</td>
<td>Extended battery lifetime 6-9 years</td>
</tr>
<tr>
<td>Usage</td>
<td>E-Bus can not be used for the complete day</td>
<td>E-Bus can be 24h in operation; no limitation</td>
</tr>
</tbody>
</table>

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Opportunity charging

Charging process is fully integrated into normal bus operations

- Bus stops are easily turned into PRIMOVE stations
- Charging stations are positioned in the depot, at start/end stops and/or en route at selected bus stops

Full day service at minimum battery size and maximum battery life for electric buses that are competitive with diesel buses

Complete PRIMOVE portfolio for true e-mobility

<table>
<thead>
<tr>
<th>Applications</th>
<th>PRIMOVE charging 200</th>
<th>PRIMOVE battery 50</th>
<th>MITRAC 500</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tram</td>
<td>PRIMOVE charging 200</td>
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<td>MITRAC 500</td>
</tr>
<tr>
<td>Bus</td>
<td>PRIMOVE charging 200</td>
<td>PRIMOVE battery 60 / 90</td>
<td>PRIMOVE propulsion 140 / 210</td>
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<tr>
<td>Truck</td>
<td>PRIMOVE charging 200</td>
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<tr>
<td>Commercial fleet</td>
<td>PRIMOVE charging 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car</td>
<td>PRIMOVE charging 3.6 / 7.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Communicating permanently
Diagnostic tool always available

Example: day 15 May 2016, one of the 18 m bus did 243 km non stop driving (without coming back to depot)
Communicating permanently

Status of all the buses and Wayside charger components is always available via an Internet communication. Some of the info available are:

- Battery charge status
- Position of each bus
- Failures on any of the buses
- Wayside availability
- Wayside components failure

Static Charge
General integration

Slab (5 m x 2.2 m x 0.25 m)
Box with components (2.8 m x 1.3 m x 1.3 m)
Cooling (0.9 m x 0.5 m x 1.8 m)
Junction box
Network connection 3 phases: ~400V/ 240kVA

Public area needed for recharging system: 45m²
Static Charge
Example on service

Electric components

Prefabricated slab for inductive recharge

Static Charge
Bus stops appearance in Berlin, Mannheim and Braunschweig

Invisible integration into the urban environment
Public Transport Development

OPPORTUNITY CHARGING FOR BUS TRANSPORTATION

1. Electric buses limitations and opportunity charging
2. Three cities having Primove installed
3. A system communicating permanently
4. Dynamic charging: tests looking forward for the future

Dynamic Charge – Example (Belgium)

Charging while driving

>100 m
Dynamic Charge – Example (Germany)

Dynamic charging tests
- Inductive charging tests
  - 1 e-bus + 1 car

Development projects
- Dynamic charging tests
  - 1 e-bus

PRIMOVE

On the road to commercial operation...

Commercial projects
- Braunschweig
  - Circular bus line
  - 1+3 e-buses
- Bruges
  - City centre line
  - 3 e-buses
- Mannheim
  - City centre line
  - 2 e-buses
- Berlin
  - City centre line
  - 4 e-buses

Development projects
- Lommel
  - Static & dynamic charging tests
  - Tram, e-bus & van
- Mannheim
  - Static & dynamic charging tests
  - 1 e-bus
- Augsburg
  - Inductive charging tests
  - 1 e-bus + 1 car

Thank you for your attention

Bombardier Transport
www.primove.com