A Vehicle Device Tailored for Hybrid Trolleybuses and Overhead Wires Implementation in SUMO

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Electrification of transportation (e-mobility) – move from combustion to electric engines

**Fully electrified PT → optimum fleet configuration and optimization of related infrastructure**

**Variants of e-buses**
- Depot-charged
- Opportunity-charged
- In-motion-charged

**Problems to solve**
- Find an optimal vehicle configuration for existing infrastructure (pre-defined set of lines, minimal infrastructure changes, etc.)
- Optimise the infrastructure for given vehicle type (re-tracing/joining lines, adding overhead wires, etc.)
- Concurrent optimisation of fleet and infrastructure (providing fully electric PT with minimal cost)
Using a traffic simulator

- Development of SW tools for **optimization** of vehicle and urban PT infrastructure configurations
- Need to **validate** results
- We want to model the electric vehicle behavior in “realistic” traffic conditions
  - to test factors that influence vehicle behavior and energy consumption,
  - to verify the vehicle configuration (vehicle dynamics, battery wear and sizing),
  - to study the influence of surrounding traffic (congestion, accidents) and the concurrent energy demands from a set of vehicles
SUMO already offers `device.battery`

Need to simulate overhead line circuit and power management strategies

Therefore: New principal objects in SUMO

- A traction substation
- An overhead wire
- A hybrid trolleybus (new device elecHybrid)
A traction substation

- To specify properties (voltage level) of PT electric network
- To provide an over-current protection and some load restriction
- In future:
  - To “control” overhead wire section
  - Communication with vehicles

<table>
<thead>
<tr>
<th>Description of parameter</th>
<th>Definition key</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substation ID</td>
<td>id</td>
<td>mandatory</td>
</tr>
<tr>
<td>Voltage</td>
<td>voltage</td>
<td>600 V</td>
</tr>
<tr>
<td>Allowed maximum current per wire</td>
<td>currentLimit</td>
<td>600 A</td>
</tr>
</tbody>
</table>
An overhead wire section and segment

- Conducts electric current from the traction substation to the vehicle
- An overhead wire **section** consists of many overhead wire **segments**

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<tr>
<th>Description of parameter</th>
<th>Definition key</th>
<th>Default value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead wire segment ID</td>
<td>id</td>
<td><strong>mandatory</strong></td>
</tr>
<tr>
<td>Lane of the overhead wire segment location</td>
<td>lane</td>
<td><strong>mandatory</strong></td>
</tr>
<tr>
<td>Voltage source connected to this segment</td>
<td>voltageSource</td>
<td>false</td>
</tr>
<tr>
<td>Start position of overhead wire segment on the lane</td>
<td>startPos</td>
<td>0.0</td>
</tr>
<tr>
<td>End position of overhead wire segment on the lane</td>
<td>endPos</td>
<td>length of lane</td>
</tr>
<tr>
<td>List of segments composing section</td>
<td>segments</td>
<td><strong>mandatory</strong></td>
</tr>
<tr>
<td>Traction substation ID</td>
<td>substationId</td>
<td><strong>mandatory</strong></td>
</tr>
</tbody>
</table>
An overhead wire electric circuit

- Direction of the movement on the lane

- Start node on positive potential
- Resistor on positive potential
- End node on positive potential

- Optional voltage source

- Start node on negative potential
- Resistor on negative potential
- End node on negative potential
An electric hybrid vehicle

- New vehicle **device.elecHybrid**
- Enables the hybrid vehicle to combine power sources (currently battery + overhead wire)
- Connects the vehicle to the overhead wire and to the corresponding electric circuit (if present)
- Basic power management enables also charging of the battery pack during motion under the overhead wire (in-motion charging)
- A simplified version for the mesoscopic mode
Kirchhoff’s laws and solving the circuit

- The hybrid trolleybus is represented as a current source.
- Voltage of overhead wire and current drawn from / recuperated to the overhead wire is computed using Kirchhoff’s laws.
Simulation – video
Evaluation – Time requirements

- Computational time depends on
  - Number of overhead wire sections
  - Number of (hybrid) trolleybuses

- Currently, the system of equations is evaluated at every simulation step for each trolleybus independently.
Conclusions & Future work

- We are able to simulate hybrid trolleybuses and their consumption with emphasis on electric quantities.
- Potentially applicable for electric trucks (eHighway or eTrucks) or a possible adoption for trams, trains.
- Speed up by evaluating the circuit only once per simulation step.
- Improving circuit solver (Newton-Raphson method).
- Future development of device.elecHybrid into a general hybrid device.

(source: Scania, PMDM)
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