THE CATENARY ERS FROM THE TRUCK PERSPECTIVE

07.-08.05.2019 / 3RD ELECTRIC ROAD SYSTEMS CONFERENCE 2019 / DR. A. SUE; DR. T. BÖHM; DR. F. WEIß
VOLKSWAGEN GROUP RESEARCH / POWERTRAIN AND ENERGY SYSTEMS
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**EXCURSUS - IMPLICATIONS OF THE PARIS CLIMATE AGREEMENT**

**PARIS AGREEMENT**

- **Article 2**
  
  (a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;

- **Article 4**
  
  1. In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

Source: UNFCCC (2015)

**GLOBAL WARMING SCENARIO CALCULATIONS**

- **Business-as-usual (4.5°C)**
- **2°C-scenarios**
- **1.5°C-scenarios**

Sources: van Vuuren et al. (2017), Rogelji et al. (2017), Schaeffer et al. (2015)

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**Volkswagen Group committed to reach the targets of the Paris climate agreement**
CO₂ EMISSIONS OF ROAD TRANSPORT

► 1/5 of the German CO₂ emissions are from traffic
► 1/3 of the CO₂ traffic emissions are from road transport

EU target of CO₂ reduction for HD CV:
15% until 2025
30% until 2030

Small amount of vehicles — big influence in CO₂ emissions!
ZERO EMISSION DRIVETRAIN FOR LONG HAUL HEAVY DUTY TRUCKS?

► In the long term the powertrain for small and medium trucks will (can) be pure electrical (BEV)
► But, what is the zero emission powertrain for the long haul ≥40 t truck?
► 500 km to 800 km per day!
► **BEV**: approx. 1.5 kWh per 1 km => 750 to 1200 kWh battery: weight, space, charging
► **FCEV**: approx. 10 kg H₂ per 100 km => 50 to 80 kg hydrogen: weight, space, costs

Is there another technology now available?
Yes, the ERS with electrical power supply via overhead wire (catenary): **The eHighway**

► Less weight because of a small battery only for gaps in the infrastructure e.g. difficult topology and electric drive from the depot to the e-highway
► Small battery means less weight and less costs
► Main question: Who will built (and pay) the infrastructure?
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HOW DOES AN OPTIMIZED SYSTEM FOR AN ERS-TRUCK LOOK LIKE?

Situation at the start of commercial use:
- very small length of electrified roads

Main goals:

*Is not pure electrical driving in any situation!* They are:
1. optimum of CO₂ reduction (LCA), costs (TCO) and weight
2. no negative influence on the logistics of the customers

Solution:

**Hybrid drivetrain (HEV) as base for eHighway trucks, pantograph charging makes it to a PHEV truck**
- basic CO₂ reduction of the HEV system
- additional reduction under the catenary due to electric driving
- charging of the battery for additional electrical driving without catenary (at once or later e.g. inner city)
COMPONENTS OF THE HYBRID DRIVETRAIN FOR eHIGHWAY TRUCKS

- DC/DC converter (charger)
- battery
- combustion engine (ICE)
- e-machine
- gearbox
- switch
- pantograph
- bypass
POWERFLOW IN DIFFERENT DRIVING MODES (SELECTION, MORE AVAILABLE)

Catenary disconnected
- ICE Drive
- Battery Electric Drive
- ICE + Electric Boost
- Recuperation

Catenary connected
- Catenary Electric Drive
- Catenary Electric Drive + Charging

Electric Power Flow
Mechanical Power Flow
COMPLEXITY OF eHIGHWAY DRIVETRAINS

PHEV

coverage with infrastructure

low (today)

high (future)

complexity/costs truck

BEV

with small battery (with range extender?)

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PROJECT INFORMATION „OBERLEITUNGS-LKW“

► title: Technologieerprobung elektrischer Antriebe bei schweren Nutzfahrzeugen und deren Energieversorgung per Oberleitung (OL-LKW)

► project partners: Volkswagen AG Group Research (leader)
Siemens Mobility GmbH

► funded by: German environmental ministry (BMU)

► project start: 01.01.2018
► project end: 31.12.2020 (duration 3 years)

► targets:
  – simulation tools and requirement for e-highway trucks
  – improvement of the robustness of the trucks for real driving including the pantograph
  – development, testing and optimization of a new pantograph generation (Siemens part)
  – analysis and optimization of other powertrain components (“next Generation”)
  – tests with 2 Scania trucks with different strong electrified power trains (type 1 and 2)
  – real drive tests on all three German test roads
  – sustainability analysis and strategical outlook

► start driving test type 1 truck: 05/2019
► start driving test type 2 truck: 10/2019
1. PROTOTYPE (BASE IS STANDARD HYBRID TRUCK)

**TYPE I TRUCK**

- **Battery** 18,5 kWh (gross)
- **DC/DC** 30 kW
- **Switch**
- **bypass**
- **ICE** 330 kW
- **EM 130 kW**
- **Gearbox**
- **DIF**
- **$U_N=670\,V\,DC$**
2. PROTOTYPE (STRONGER ELECTRIFIED)

TYPE II TRUCK

- 4 x Battery
- 74 kWh (gross)

DC/DC
- 180 kW

ICE
- 330 kW

EM

> > > > 130 kW

Gearbox

DHT: Dedicated Hybrid Transmission

DIF

UN=670 V DC
STATUS BUILD-UP 1ST TRUCK ("EL CAMINO")
For the simulation of typical transportation a standard trailer is rented (13,675m/12,000m)

For the variation of the load the trailer is equipped with concrete blocks (12 x 2,1 t)
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GOALS OF THE Catenary ERS TECHNOLOGY
AND ITS DEPENDENCIES FROM THE TRUCK POINT OF VIEW

Electric motor: power/torque
Battery: capacity, power
Hybrid management software
ICE: power/torque
DC/DC-converter: power/current

Overhead wire (OW) coverage:
  location, share, length, ...
Transmission: gear ratio,
  number of gears

CO₂
TCO
ADEQUATE SHARE OF THE OVERHEAD WIRE
LONG HAUL SCENARIO

**Simulation premises:**
- 35 t long haul truck: sufficient drivability with 330 kW system power (no ICE start if EMs can perform at least 330 kW)
- Optimal distributed OW-segments, no OW-power limit
- Example routes BS-Magdeburg and Koblenz-Trier
- Long Haul scenario: Balanced battery SOC

*Potentially local CO2 benefit [%]
OW-share [%]

100% local CO2-benefit is not reached due to power related ICE-starts
Saturation of the CO₂-benefit at 30-50% OW-share, higher share has a small effect.
SENSITIVITY ANALYSIS
LONG HAUL SCENARIO

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With increased motor power, complete pure electric driving is possible from 40% OW-share on.
SENSITIVITY ANALYSIS
LONG HAUL SCENARIO

With increased motor power, complete pure electric driving is possible from 40% OW-share on.
Increasing the max. charging power (battery and DC/DC), the potential CO₂-benefit rises significantly.

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Range caused by different routes

potential local CO₂ benefit [%]

OW-share [%]

0 20 40 60 80 100

0 10 20 30 40 50 60 70 80 90 100

type II truck

type II truck + increased peak EM-power

type II truck + doubled battery AND doubled DC/DC-power

Effect of Hybridization: recuperation, E-drive, load shift, ...

With increased motor power, complete pure electric driving is possible from 40% OW-share on.
Increasing the max. charging power (battery and DC/DC), the potential CO₂-benefit rises significantly.

*compared to a conventional 35 t Truck
CONCLUSION: COMPLEX FINDING OF THE OPTIMUM

The optimum of CO₂ reduction, truck performance and costs is a complex function.
Thank you for your attention!