Optimal Energy Consumption and Recovery
Based on a system network

Project Status

Joint EC / European Green Cars Initiative Workshop 2013
Electric Vehicle Systems Architecture and Standardization Needs

2013/10/23 Brussels

Dr. Kosmas Knødler
Robert Bosch GmbH
OpEneR project overview
Vehicle and subsystem integration
Energy management functions
From office simulation to testbed
Conclusion and outlook
OpEneR 3008 4WD performance
OpEneR is developing driving strategies & assistance systems, that increase electric vehicle efficiency, driving range & safety.

This is achieved by merging data from on-board & off-board sources. A particular focus lies on an optimal cooperation between the electric drivetrain and the regenerative braking system, supported by data from radar, video, satellite navigation, car-to-infrastructure & car-to-car systems.

Overall project budget: 7.7 Million €
Testing of OpEneR prototypes

Sensing Traffic & Environment Conditions

Weather Cond.
Weather Cond.
Traffic Jams
Traffic Jams
Road Works
3D Road

Integration of Complex Subsystems
Powertrain, Subsystems
Car2x
ESP®, iBooster
Satellite Navigation
Radar, Video

Software Development Process – Technology Levels
OpEneR Vehicle Development
Level 0
Level 1
Level 2
Level 3

03/2013 OpEneR prototypes n°1 and n°2 in winter testing
01/2012 OpEneR prototype n°1 in winter testing
06/2013 OpEneR prototype n°1 on 2nd Project Review in Boxberg
04/2013 OpEneR prototype n°1 on Boxberg Test Track
05/2014 Function Demonstration

Validation measurements, function validation
Validation measurements, function validation
Coasting assist, torque distribution and regenerative braking
Enhanced coasting assist, torque distribution and regenerative braking

05/2013 OpEneR prototype in wind channel in Paris
12/2012 OpEneR prototype n°1 on Boxberg Test Track
05/2013 OpEneR prototype in wind channel in Paris
05/2013 OpEneR prototype n°2 on Graz dynometer testbed
04/2013 OpEneR prototype n°1 on Boxberg Test Track
05/2013 OpEneR prototype in wind channel in Paris

Public Road
Release 11/2013

Full OpEneR Energy Management Technology demonstrated on public road
05/2014 Final demonstration event in Vigo, Spain, on public intelligent corridor
OpEneR project overview
Vehicle and subsystem integration
Energy management functions
From office simulation to testbed
Conclusion and outlook
OpEneR 3008 4WD performance
Vehicle topology

3008 Hybrid4

**Rear axle**
- 27 kW/200Nm
- e-machine, HV NiMH
- battery and all-in-one
- DCDC & double inverter

**Front axle**
- 120 kW/300Nm
- Diesel engine with
- HV Stop/start 8kW generator

3008 OpEneR
Vehicle topology

3008 Hybrid4

3008 OpEneR
Vehicle topology

3008 Hybrid4

- 2x50kW e-machine
- 40kWh battery package
  - 4x125kg package in serial connection
  - FePO4 technology
  - 36,8 kWh usable capacity (200km range)
  - 110kW discharge and charge (depending on temp.)

- Thermal management
  - 2 radiators for inverters/e-machines and battery
  - Water heating via 2x 6kW CTP (cockpit & battery)
  - Electric A/C compressor with double circuit (battery & cockpit)

- Body & chassis design
  - New Body design for battery integration
  - General behavior similar to 3008 hybrid4 (+200kg)
  - Body Stiffness same as or better than serial production

3008 OpEneR
New braking systems

Components

Brake boost → Vacuum-free & autonomous braking
- Vacuum Booster
- iBooster

Modulation → Recuperation
- ESP®
- ESP®hev

Use cases

Target vehicles
- standard vehicle with ICE
- ICE vehicle w/ high performance driver assistance (HPDA*)
- Hybrid vehicle (mHEV, sHEV)
- PHEV/EV-vehicle or Hybrid with HPDA

Setup

Target vehicles
- standard vehicle with ICE
- ICE vehicle w/ high performance driver assistance (HPDA*)
- Hybrid vehicle (mHEV, sHEV)
- PHEV/EV-vehicle or Hybrid with HPDA

* high performance driver assistance requiring highest pressure dynamics

Functions

- Vacuum free braking force amplification
- Support of energy recuperation via two e-machines
- Blending between electric e-machine torque and friction torque
- iBooster for active brake pressure build-up

OpEneR
**New braking systems**

### Components

**Brake boost → Vacuum-free & autonomous braking**
- Vacuum Booster
- iBooster

**Modulation → Recuperation**
- ESP®
- ESP®hev

---

**Use cases**

**Target vehicles**
- Standard vehicle with ICE
- ICE vehicle w/ high performance driver assistance (HPDA*)
- Hybrid vehicle (mHEV, sHEV)
- PHEV/EV-vehicle or Hybrid with HPDA

**Setup**
- Vacumm Booster
- iBooster
- ESP®hev

* high performance driver assistance requiring highest pressure dynamics

---

**Setup**
- Actuation
- Power
- Modulation
- Foundation

---

**Graph**

- Brake torque
- Deceleration

- Regenerative brake torque
- Speed

---

**Logo**

- OpEneR
- iBooster
- ESP®hev
ADAS in OpEneR

Components

- Ultrasonic sensors
- Long range radar
- Mid range radar rear
- Mid range radar plus
- Multi purpose camera
- Near Field camera
- Night Vision camera

OpEneR

Functions

- Traffic Signs, objects, lanes
- Eco ACC w/ Stop & Go
- Blind Spot Detection
- Lane Change Assist
- Rear Cross Traffic Alert
ADAS in OpEneR

Components

- Ultrasonic sensors
- Long range radar
- Mid range radar rear
- Mid range radar plus
- Multi purpose camera
- Near Field camera
- Night Vision camera

OpEneR

- Multi purpose camera
- Long range radar
- 2x Mid range radar rear
New HMI including SatNav

- New HUD
- TFT Instrument Cluster
- Original Display removal
- Navigation system (iPad based)
- Climate & audio reallocation
- Gearbox selector replacement
- Gearbox selector & mode selector

New Steering wheel commands
New HMI including SatNav
New HMI including SatNav
New HMI including SatNav

- TFT Dashboard
- HUD
- Steering column controls
- iPad
- DIN Audio Module
- Climate Module
- Gear selector
- Mode selector
An active pedal supports the driver with **haptic** signals while driving.

Signals are possible as:

- **Knocking**
- **Vibration**
- **Force feedback**
- **Variable kick-down**
- (Parallel force increase)

Warning signals from **different connected systems** can be sent to the driver.
E/E-architecture
Energy management functions

Driver

Situation and Environment

Vehicle System

Electrical Consumer

Powertrain
Energy management functions

Driver

Situation and Environment

Vehicle System

Energy Manager

Driver

Electrical Consumer

Powertrain
Energy management functions

- Driver
- GPS / Digital Map
- C2X
- Radar
- Video
- Misc. Sensors
- Battery Sensors
- E-Drive Controller 1
- E-Drive Controller 2

- Coasting Assistant
- Recuperation Management
- Acceleration Management
- Torque Distribution
- Electr. Consumer Management
- Short Term Energy Forecast
- Electr. Consumer Energy Forecast
- Situation Analysis
- Statistical Data Makro Model

Level 1
Level 2
Level 3
Energy management functions

- Energy Efficient Route Calculation
- ESP®hev: 2-channel Cooperative Regenerative Braking
- TCS – Distributed e-Machine Control
- Torque Distribution
- Coasting Assistant
- Energy efficient ACC
- Acceleration Assistant
- Energy-efficient auxiliaries
- OpEneR project overview
- Vehicle and subsystem integration
- Energy management functions
- From office simulation to testbed
- Conclusion and outlook
- OpEneR 3008 4WD performance
- 40kWh battery package (200km range)
- 110kw discharge and charge (depending on temp.)
- Front & Rear Axle e-traction i.e. e-4WD
- Recuperation (e-braking) with ESP® hev + iBooster
OpEneR co-simulation environment including the AVL CRUISE powertrain and Bosch ESP® hev model
Simulation toolchain extensively supports development process

- AVL InMotion test-bed
  - Fast migration to HiL testing
  - Rapid prototype testing
  - Realistic real-world conditions
  - Complex interface between Unit Under Test, automation and measurement systems

Reuse of office simulation environment for AVL InMotion test-bed

Office → Lab → Testbed → Road
Outline

- OpEneR project overview
- Vehicle and subsystem integration
- Energy management functions
- From office simulation to testbed
- Conclusion and outlook
- OpEneR 3008 4WD performance
Eco ACC function is currently under evaluation
OpEneR successfully cooperated eFuture in the field of evaluating eco ADAS functions
OpEneR consortium keeps on working on
- Architecture, scalability, modularity, and metrics
- Energy efficient and safe speed modulation
- Energy efficient and safe Torque Split
- Energy efficient auxiliary consumers
Public road release
Afterwards Car-to-X units will be integrated at CTAG
- Integration and evaluation of Car-to-X related functions
- Final testing and proving during last project review in Vigo, Spain
Prototype build-up
Paris, Dec. 2011

Winter testing
Ariéplog, Jan. 2012

1st project review

Testing period

Winter testing
Vaitoudden, Mar. 2013

Wind tunnel
Paris, Apr. 2013

4-wheel dynamometer
Graz, May. 2013

2nd project review
Boxberg, Jun. 2013

RIVE2013
Alès, Jul. 2013
OpEner will exhibit on Stand 5E13 Nov. 6th until Nov. 8th

Outlook

Prototype build-up
Paris, Dec. 2011

1st project review

Winter testing
Ariège, Jan. 2012

Testing period

Wind tunnel
Paris, Apr. 2013

4-wheel dynamometer
Graz, May. 2013

2nd project review
Boxberg, Jun. 2013

RIVE2013
Alès, Jul. 2013
Outline

- OpEneR project overview
- Vehicle and subsystem integration
- Energy management functions
- From office simulation to testbed
- Conclusion and outlook
- OpEneR 3008 4WD performance
OpEneR prototypes proved performance on several events, e.g.

- Two winter testing periods
- Testing periods on partner's proving grounds
- AVL's 4-wheel dynamometer testbed
- RIVE2013
Thanks for your attention
Any questions?