Model-based Software Development Demonstrated on a Compressed-Natural-Gas Hybrid Electric Vehicle

Modellbasierte Softwareentwicklung am Beispiel eines Erdgas-Hybridfahrzeugs

9. Internationales Stuttgarter Symposium Automobil- und Motorentechnik
25. März 2009

Michael Böhm
Outline

1. Introduction
2. Hybrid Control Unit
3. Power Train Control
4. Summary and Outlook
Drive Concept based on Natural-Gas Hybrid Technology

- Partners

- Supported by

- October 2006 till end of 2009
Development Targets

- Usage of small displacement turbocharged CNG engine, still good driveability
- Minimized CO\textsubscript{2}-Emission (≤90 g/km in NEDC)
- Fullfillment of future emission legislation (EURO 5) through
  - Hybridization
  - Use of CNG as fuel
  - Monovalent layout of combustion engine
- Integration of a forward looking, self learning driving strategy
Vehicle Concept

- Opel Astra Caravan

1.0 L
71 kW
160 Nm
155 Nm
35 kW
160 Nm
Outline

1. Introduction

2. Hybrid Control Unit

3. Power Train Control

4. Summary and Outlook
Motivation for a Hybrid Control Unit

- Integration of hybrid components in existing vehicle bus system
- Enable hybrid operation
- Set reference values for
  - Combustion engine
  - Electric machine
  - Clutches
  - Gearbox
  - Battery

new control unit
Software Structure of the Hybrid Control Unit

- Input
- Operating surveillance
- Operating strategy
- Power train control
- Signal processing
- Safety & limiter
- Output
Change between Operating Points

- Reference values from operating strategy
  - \( \mathbf{v} = (M_{\text{eng,OS}}, M_{\text{em,OS}}, \text{gear}, \text{mode}) \)
Interconnection between OS, PTC and Vehicle

Hybrid Control Unit

- Operating strategy
- Power train control
- Gear control

M\textsubscript{eng,OS}
M\textsubscript{em,OS}/n\textsubscript{em,OS}
gearing
mode

M\textsubscript{eng,PTC}
M\textsubscript{em,PTC}
gearing
M\textsubscript{clu1,PTC}
M\textsubscript{clu2,PTC}
Software Development Process

- Requirements
  - In parallel to setup of the vehicle
  - Preliminary software testing
  - Easy integration in vehicle

- Virtual development environment
  - Models for vehicle, driver and cycle
  - Separation between components and ECUs
  - Modular structure
  - Real-time capability
  - Same interface as in vehicle
  - Considering bus communication
Software Development Process
Outline

1. Introduction
2. Hybrid Control Unit
3. Power Train Control
4. Summary and Outlook
Functionality of the Power Train Control

- Change reference values from OS to reference values for vehicle
- Optimization of the driving comfort
- Starting-up and shutting down the vehicle
- Emergency shutdown
- Consider torque requests from ABS/ESP and gearbox
Main Operational States

- combined operation
- start-up/shutdown
- electric operation
- charging during standstill
Example: Change from Combined to Electric Operation

- Sequence of reference values
Example: Change from Combined to Electric Operation

- In-vehicle measurement

![Graph showing changes in torque and speed during a transition from combined to electric operation.](image-url)
Example: Change from Combined to Electric Operation

- Example for a bad change

![Graph showing torque and speed over time]
Example: Change from Combined to Electric Operation

- Comparision between vehicle and simulation

![Graph showing torque and speed comparison between vehicle and simulation](image)
Outline

1. Introduction
2. Hybrid Control Unit
3. Power Train Control
4. Summary and Outlook
Summary and Outlook

- Hybrid specific software consists of more than an operating strategy
- Suitable software development process needed
  - Offline
  - HiL
  - Driving simulator
  - Vehicle
- Intelligent powertrain control
Summary and Outlook

- Further optimization of OS and PTC under energetic and comfort aspects
- Integration of forward looking information into operating strategy
- Driving tests
Model-based Software Development Demonstrated on a Compressed-Natural-Gas Hybrid Electric Vehicle

Modellbasierte Softwareentwicklung am Beispiel eines Erdgas-Hybridfahrzeugs

9. Internationales Stuttgarter Symposium Automobil- und Motorentechnik
25. März 2009

Michael Böhm