

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

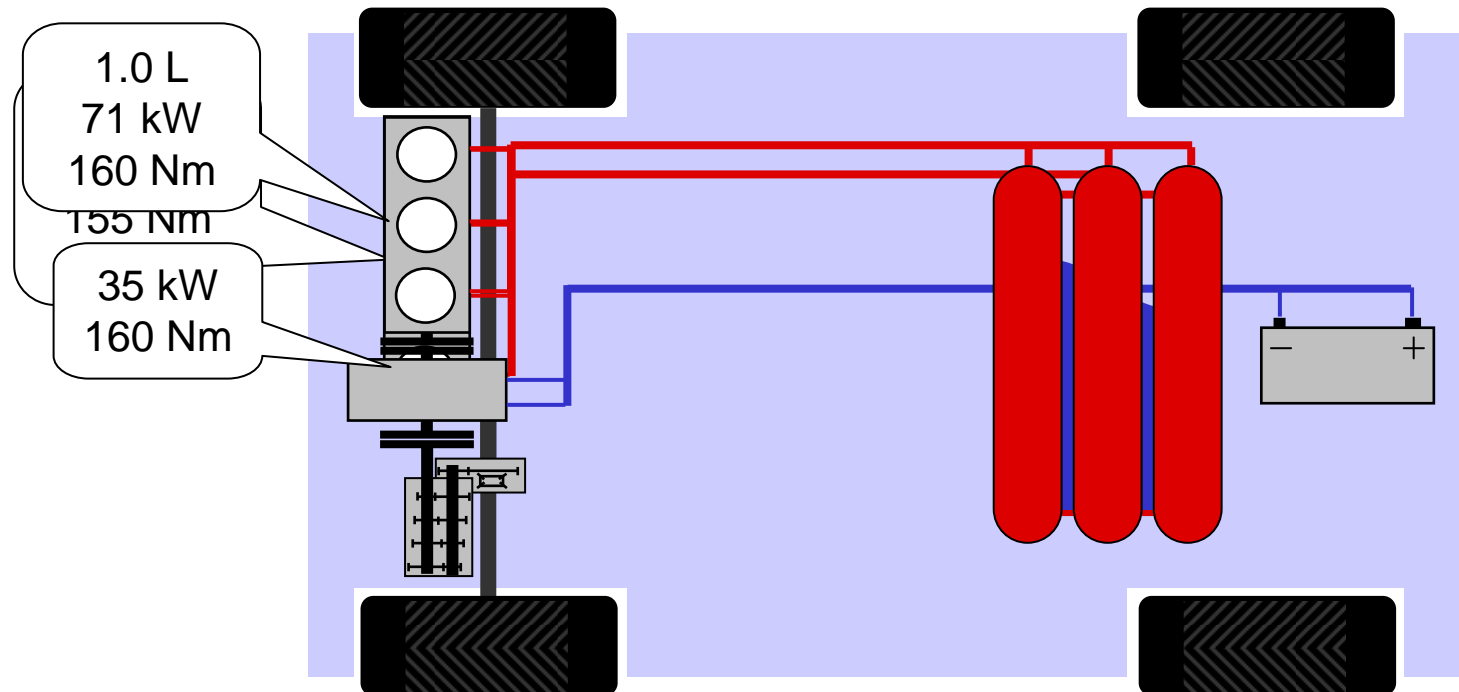
Development Targets

- Usage of small displacement turbocharged CNG engine, still good driveability
- Minimized CO₂-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

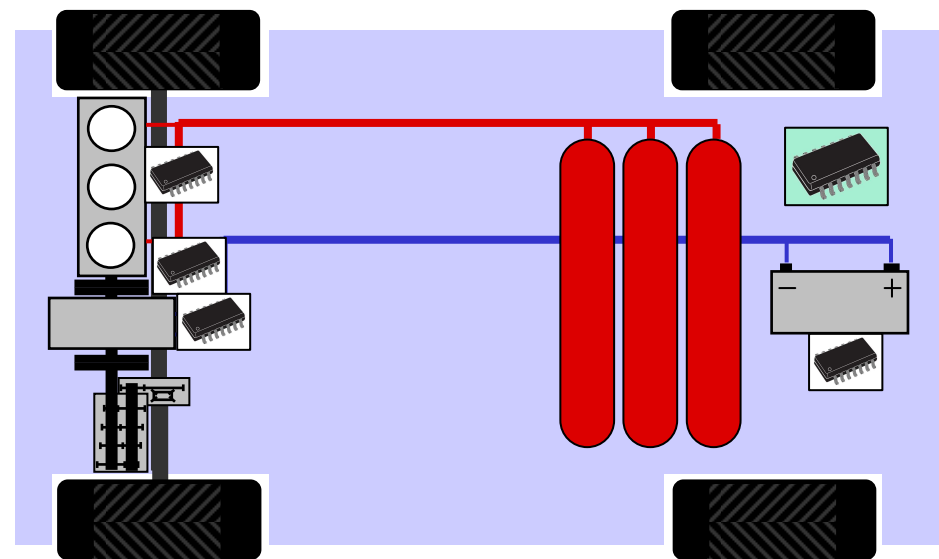


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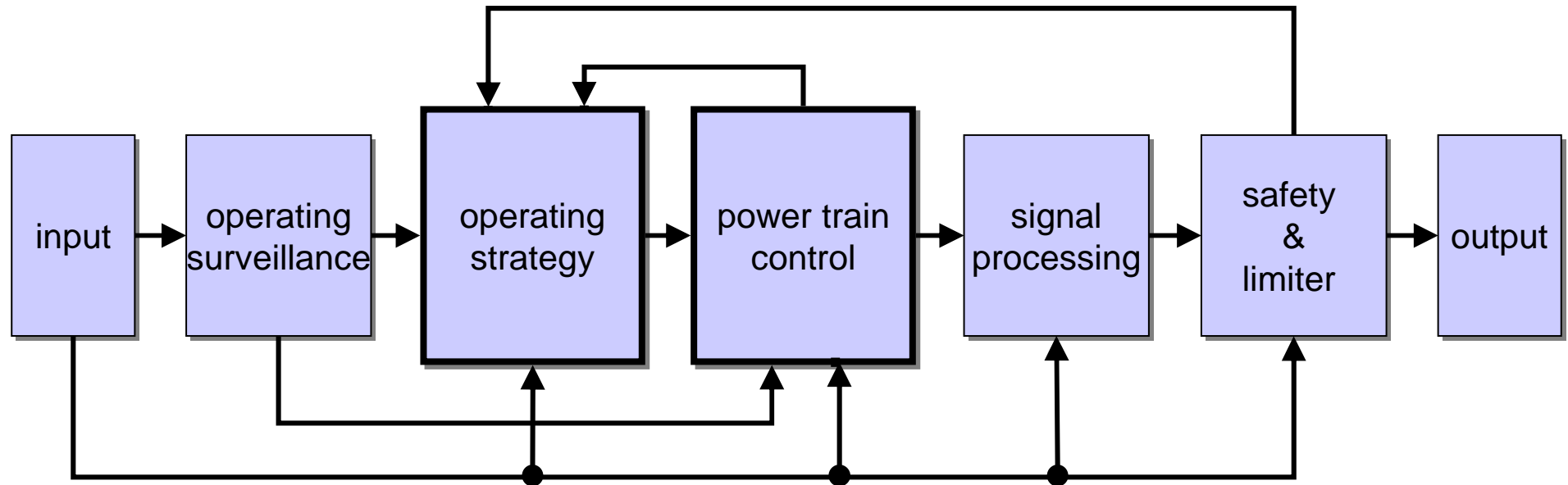
Motivation for a Hybrid Control Unit

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



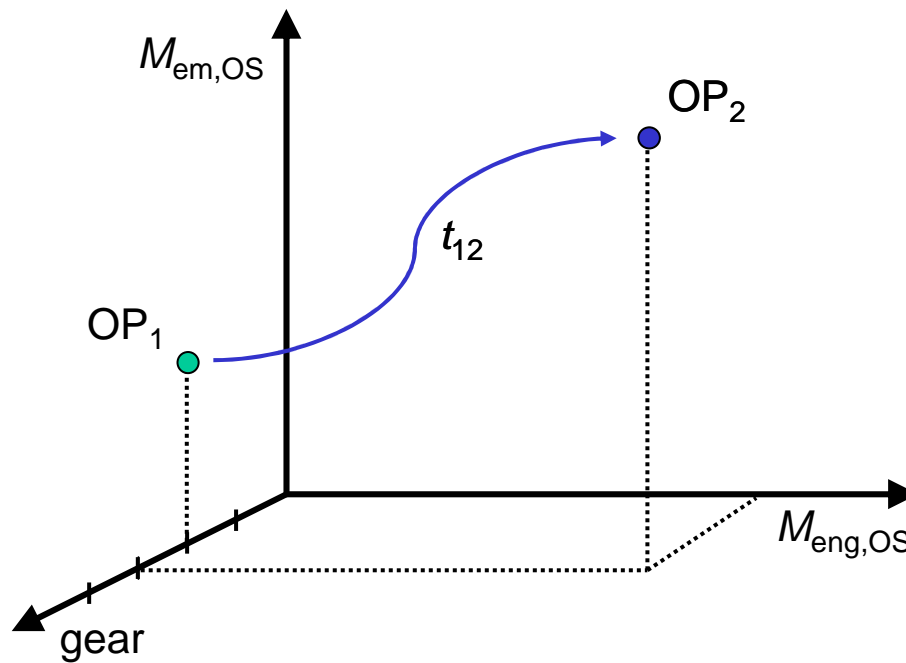
 new control unit

Software Structure of the Hybrid Control Unit



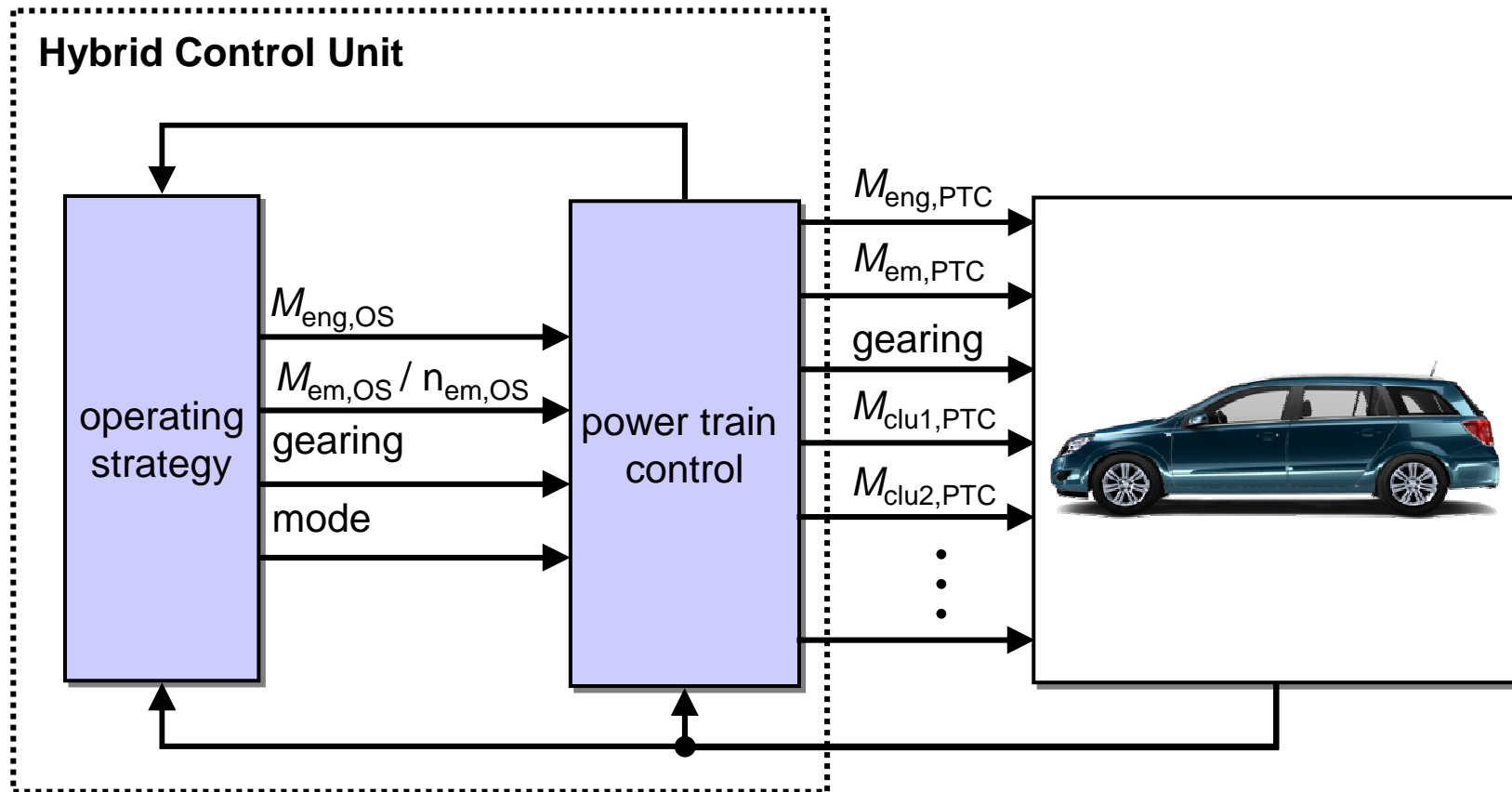
Change between Operating Points

- Reference values from operating strategy
 - $\mathbf{v} = (M_{eng,OS}; M_{em,OS}; gear; mode)$



- electric operation
- combined operation

Interconnection between OS, PTC and Vehicle



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

www.ivk.uni-stuttgart.de

offline simulator

HiL simulator

driving simulator

vehicle

real-time system



HCU

HCU

HCU

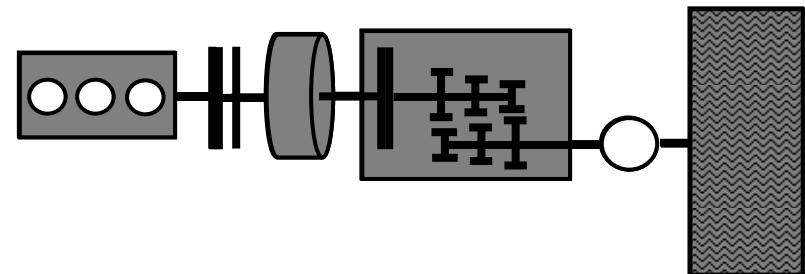
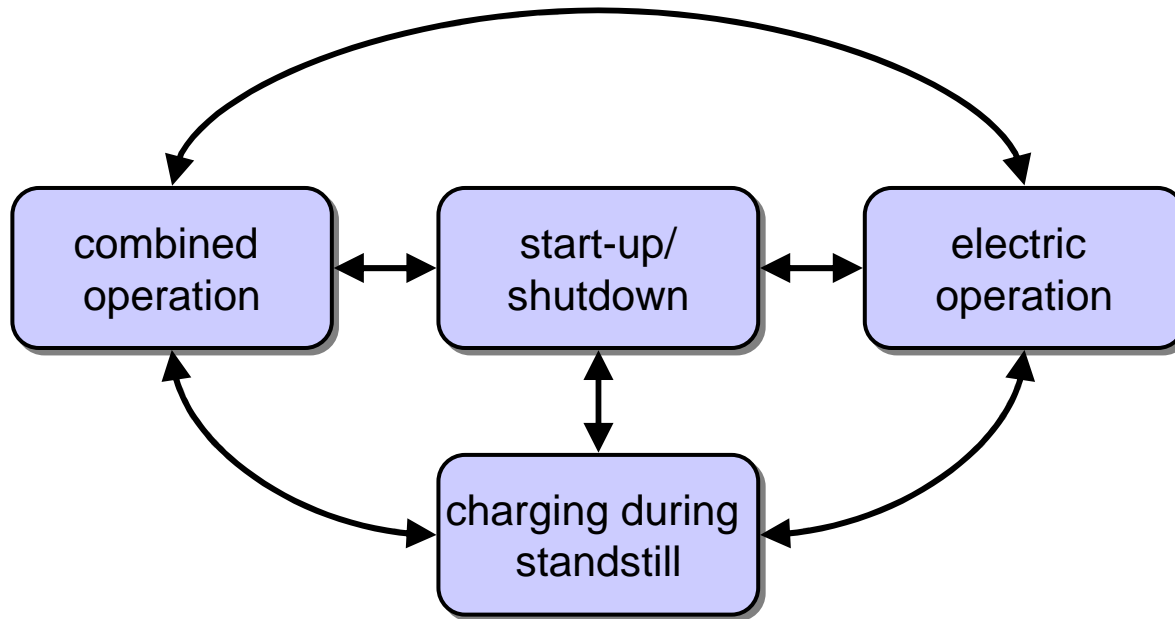
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Functionality of the Power Train Control

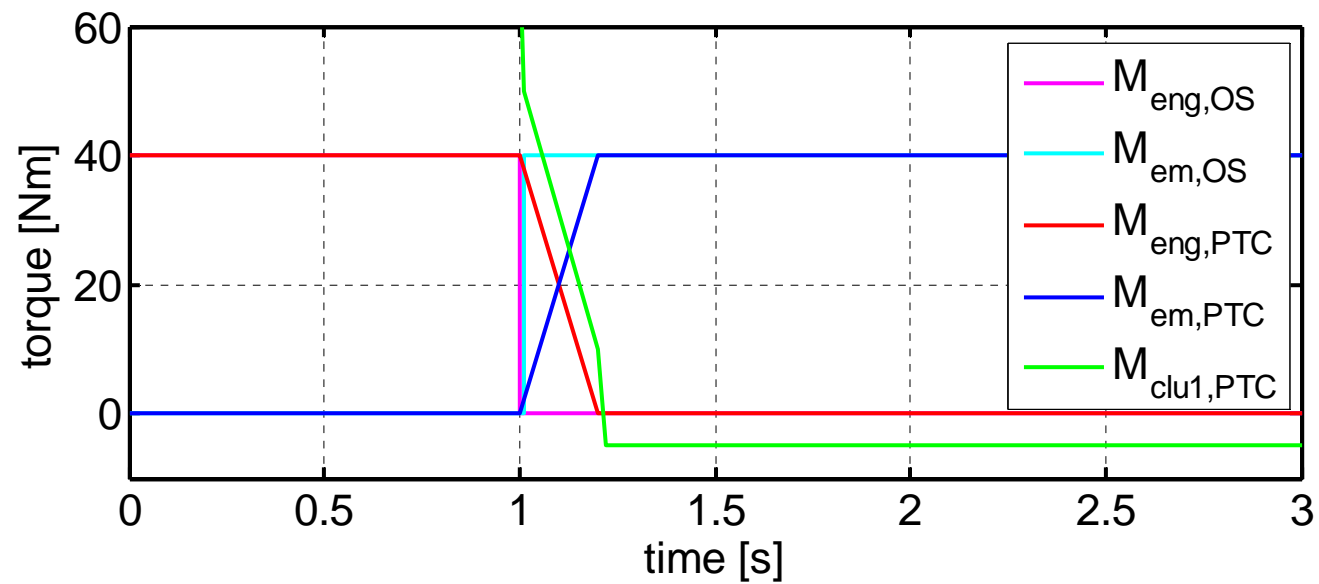
- Change reference values from OS to reference values for vehicle
- Optimization of the driving comfort
- Starting-up and shutting down the vehicle
- Emergency shutdown
- Consider torque requests from ABS/ESP and gearbox

Main Operational States



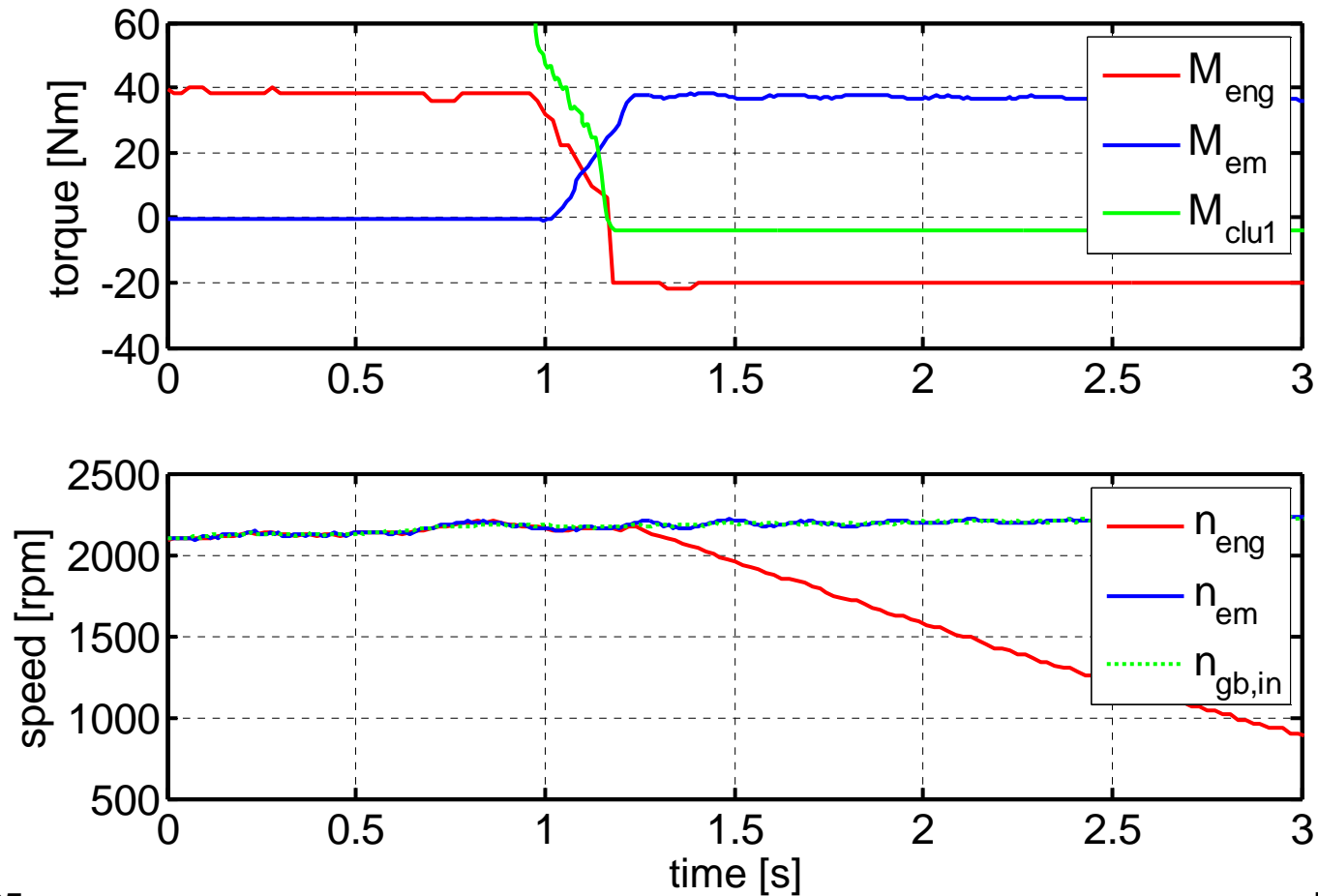
Example: Change from Combined to Electric Operation

- Sequence of reference values



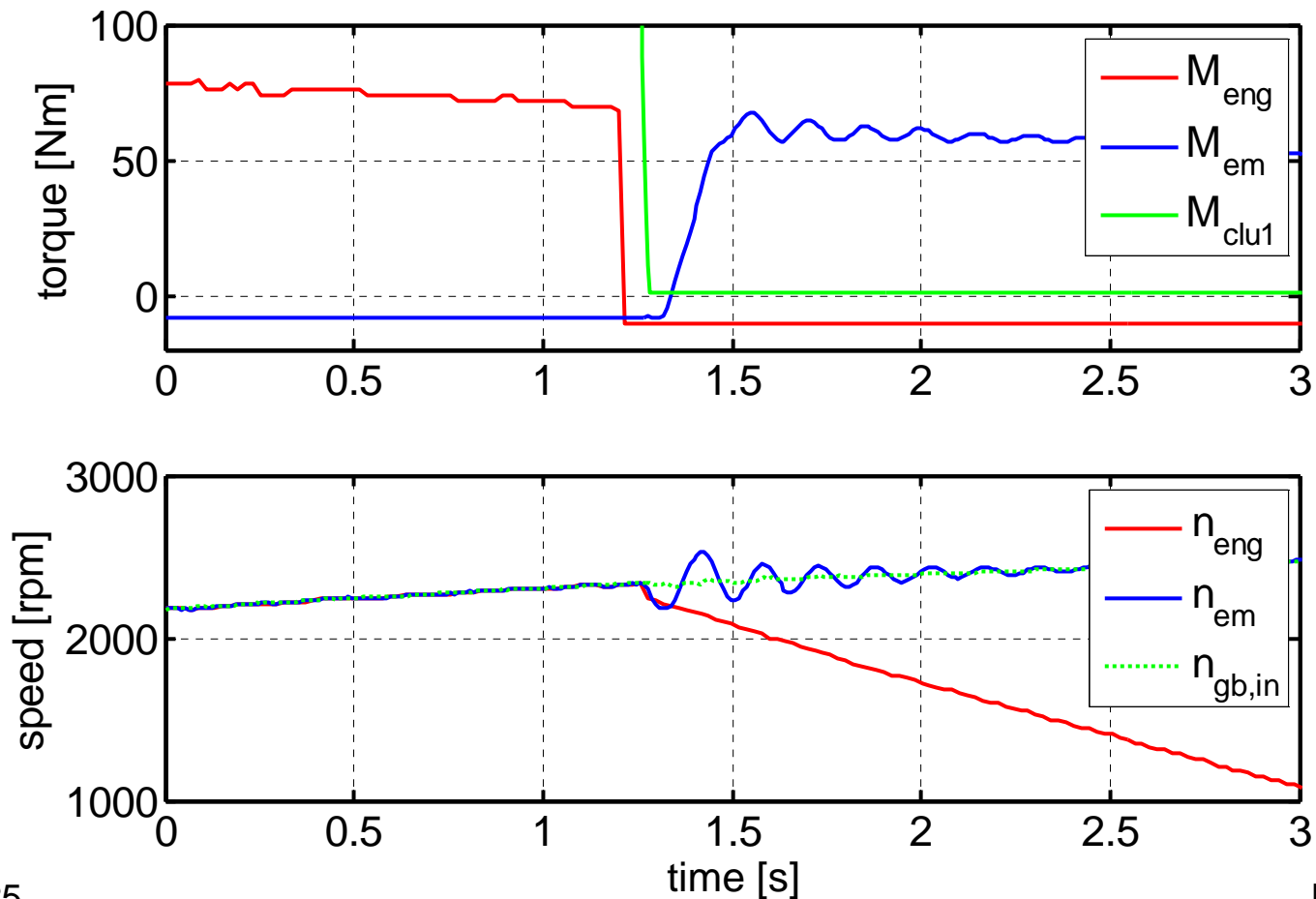
Example: Change from Combined to Electric Operation

- In-vehicle measurement



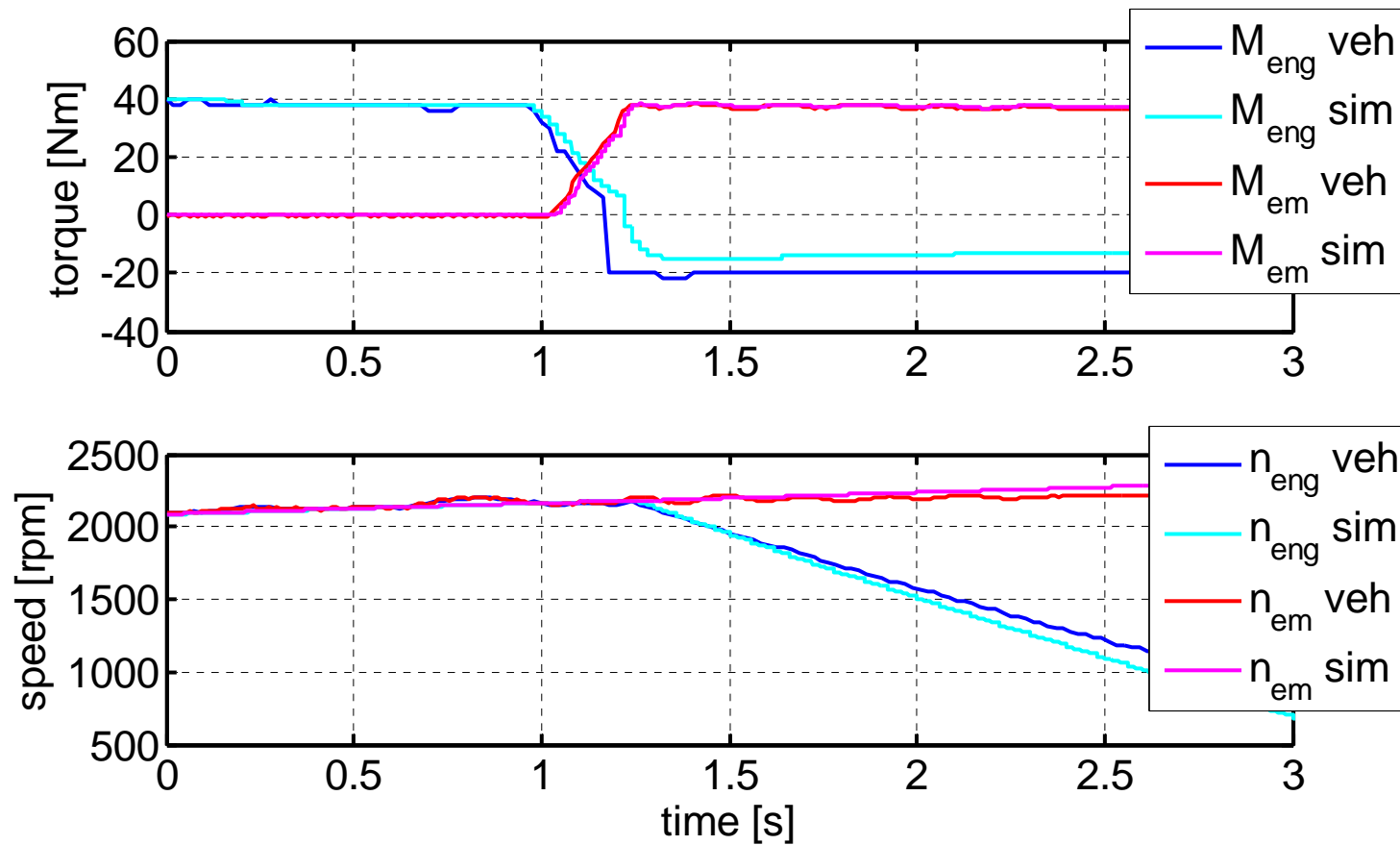
Example: Change from Combined to Electric Operation

- Example for a bad change



Example: Change from Combined to Electric Operation

- Comparison between vehicle and simulation



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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



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