Determination of Saving Potential for a Parallel Hybrid Power Train

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  - Approach
- Modelling
- Optimization
- Results

Introduction

- Motivation
- Approach

Motivation

- Determine optimal fuel consumption/emission of a given vehicle over a given driving cycle
- Make absolute evaluation of operation strategies possible
- Collect information on how to control the components of a hybrid drivetrain in an optimal way

Approach

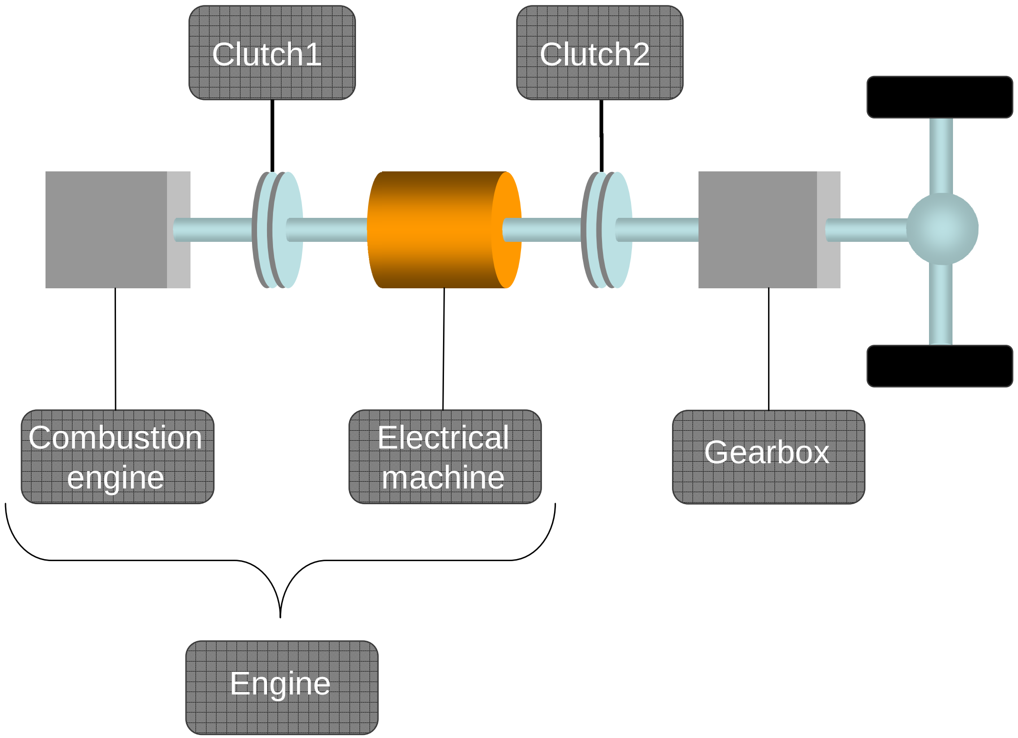
- Develop a mathematical vehicle model
- Perform optimization run over given driving cycle using appropriate optimization method

Modelling

Vehicle model – required components

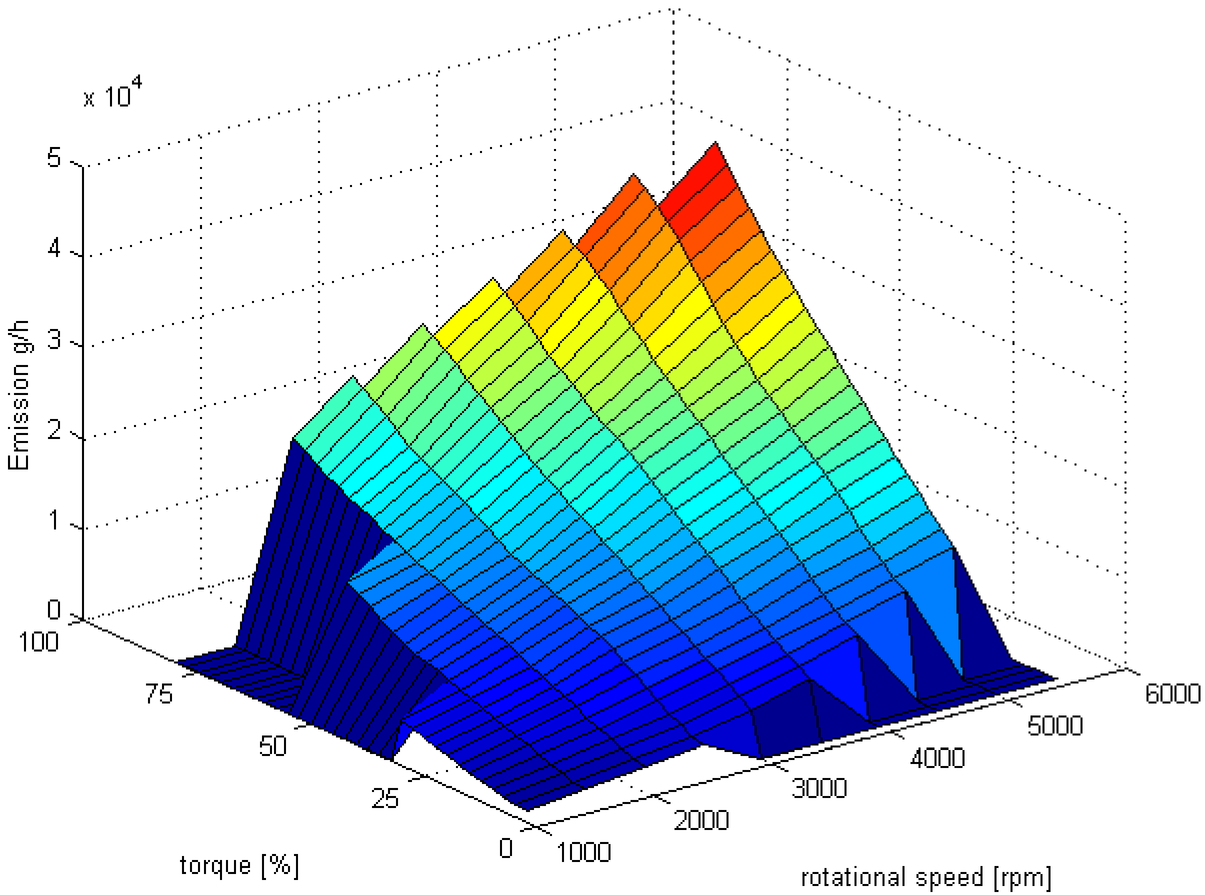
- Driving resistances
- Power train
  - Axle and gearbox
  - Internal combustion engine
  - Electrical machine
  - Battery

Drivetrain structure
Parallel-hybrid



- Parallel configuration
- Manual Transmission Automatically Shifted
- Additional clutch, enabling electric drive mode
- HV electrical system

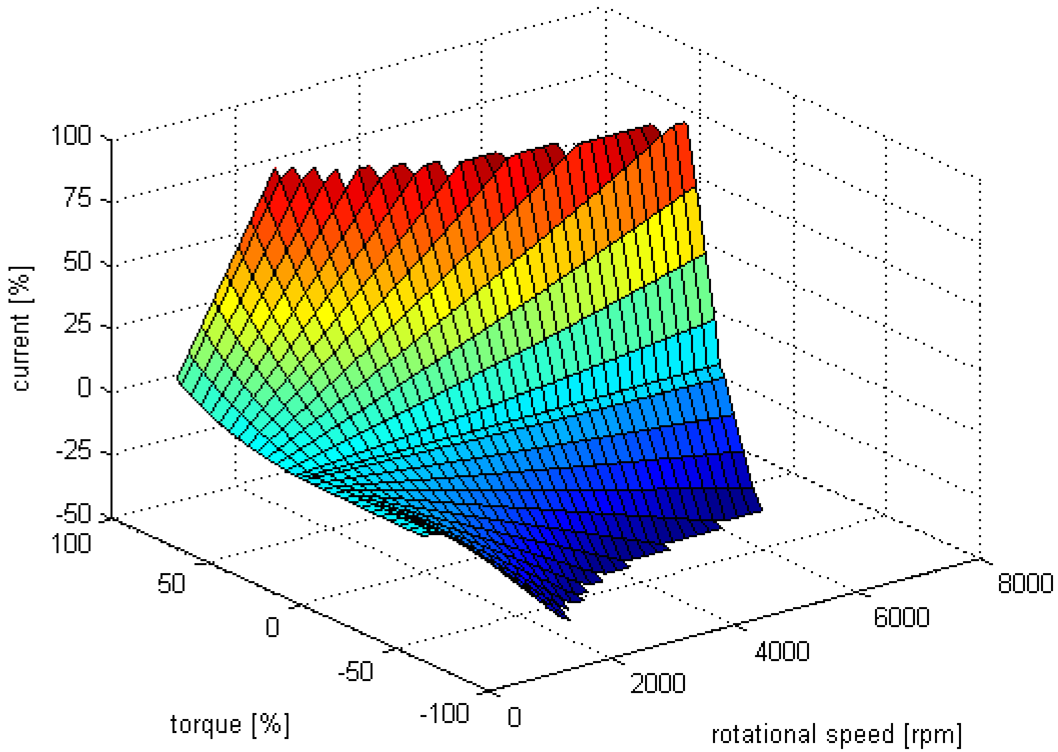
Combustion engine
3-cylinder turbocharged CNG-engine



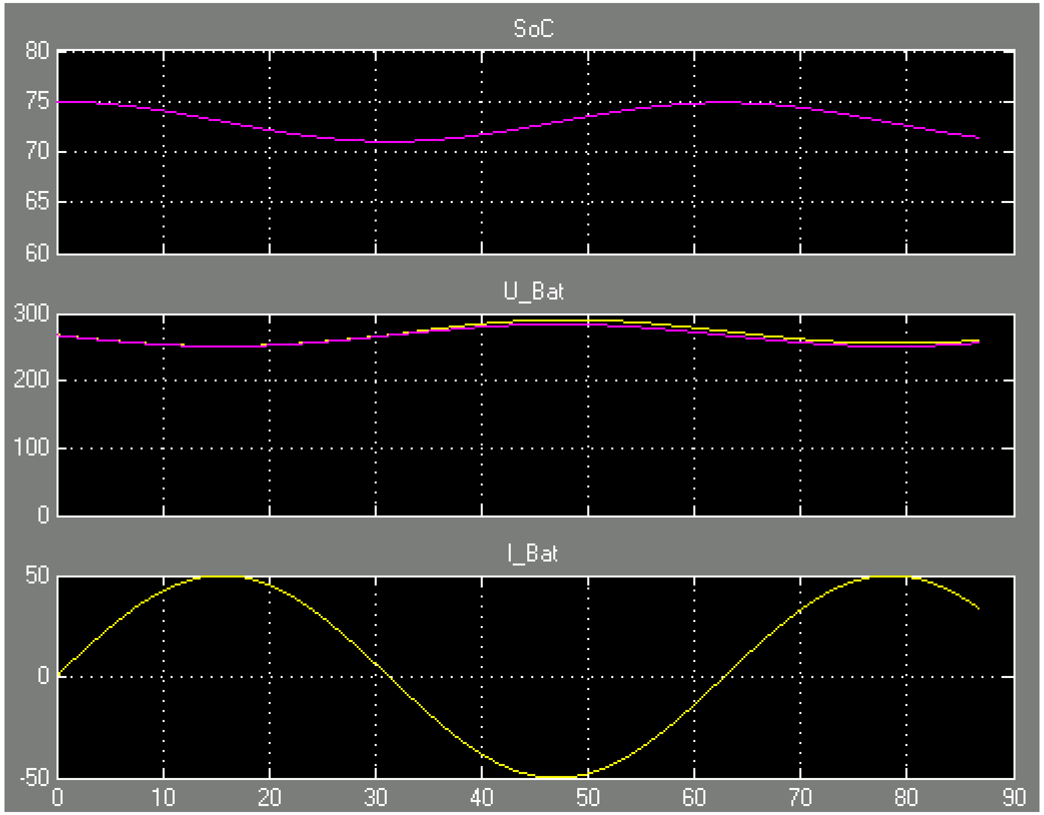
Max. power: 71 kW

Electrical engine

Max. power 22 kW



High-voltage battery



- NiMH type
- Nominal Voltage: 255 V
- Capacity: 7 Ah

- Battery voltage sum of cell-voltage and internal resistance

$$SoC(t) = \frac{1}{C_{bat}} \times \int_{t_0}^{t} I(t)dt + SoC_0$$

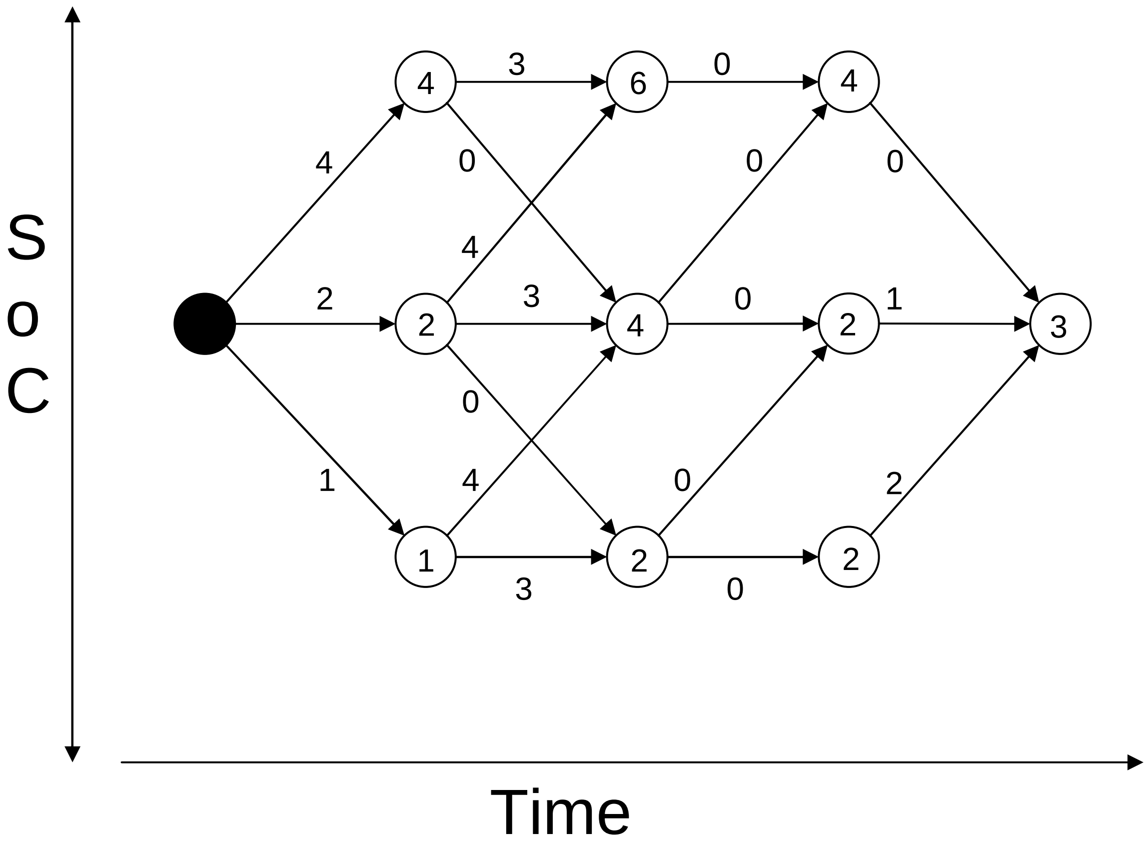
$$U_{term} = U_i(SoC) + I \times R_i$$

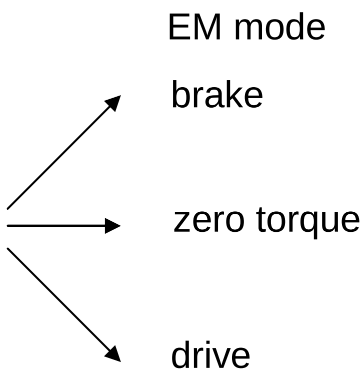
Simulation parameters

- NEDC driving cycle
- Δt=0.5 s, 2360 simulation steps
- SoC: 60-80 %, 1000 steps, 0.2 ‰ resolution
- Backward-simulation: driving cycle (speed) causes driving power, which reverses regular causal-chain
- Recuperation torque limited to one third of required deceleration torque due to conventional brake system in the car

Optimization

Dynamic Programming applied for hybrid vehicle optimal control



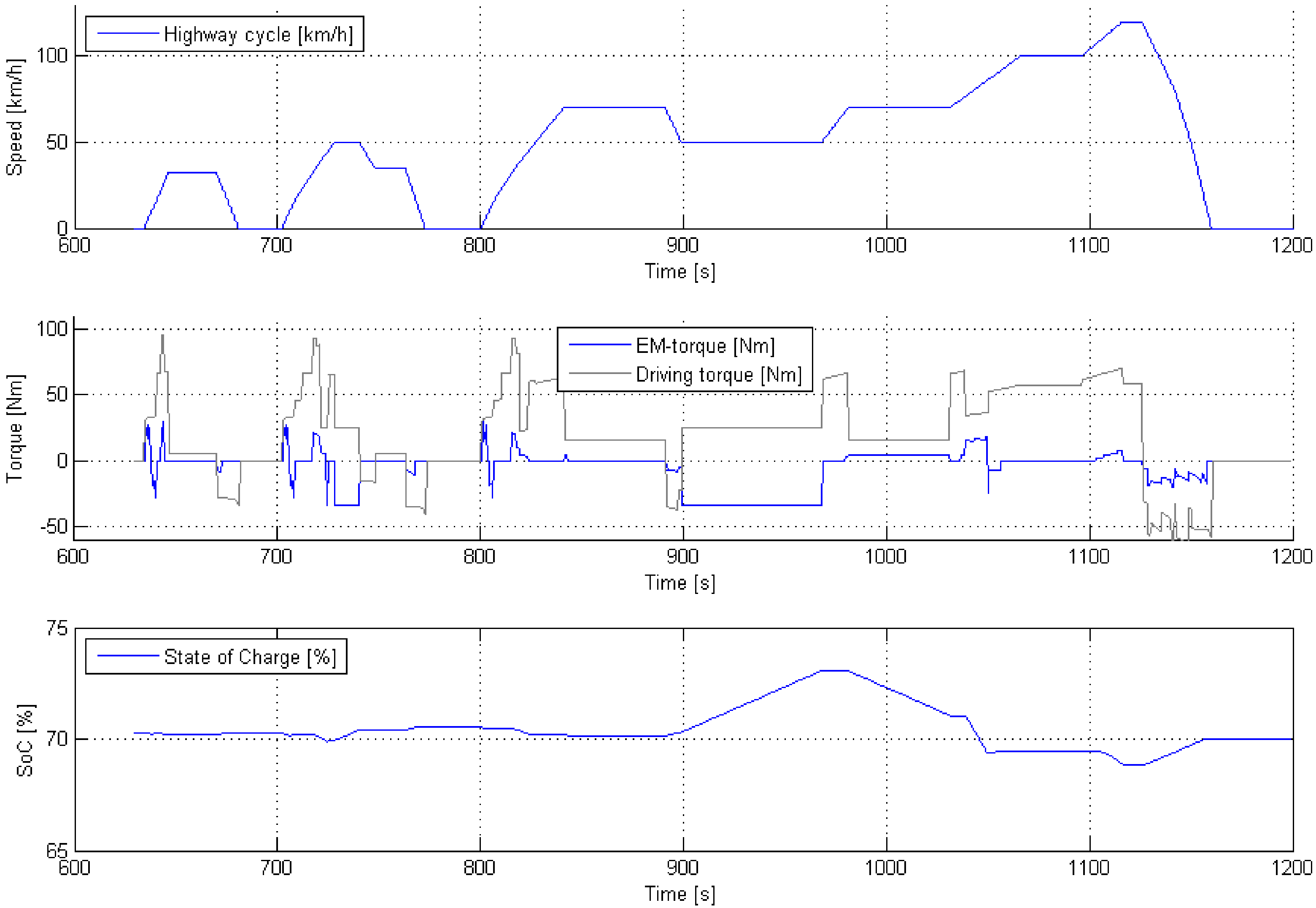


Dynamic Programming applied for hybrid-vehicle optimal control

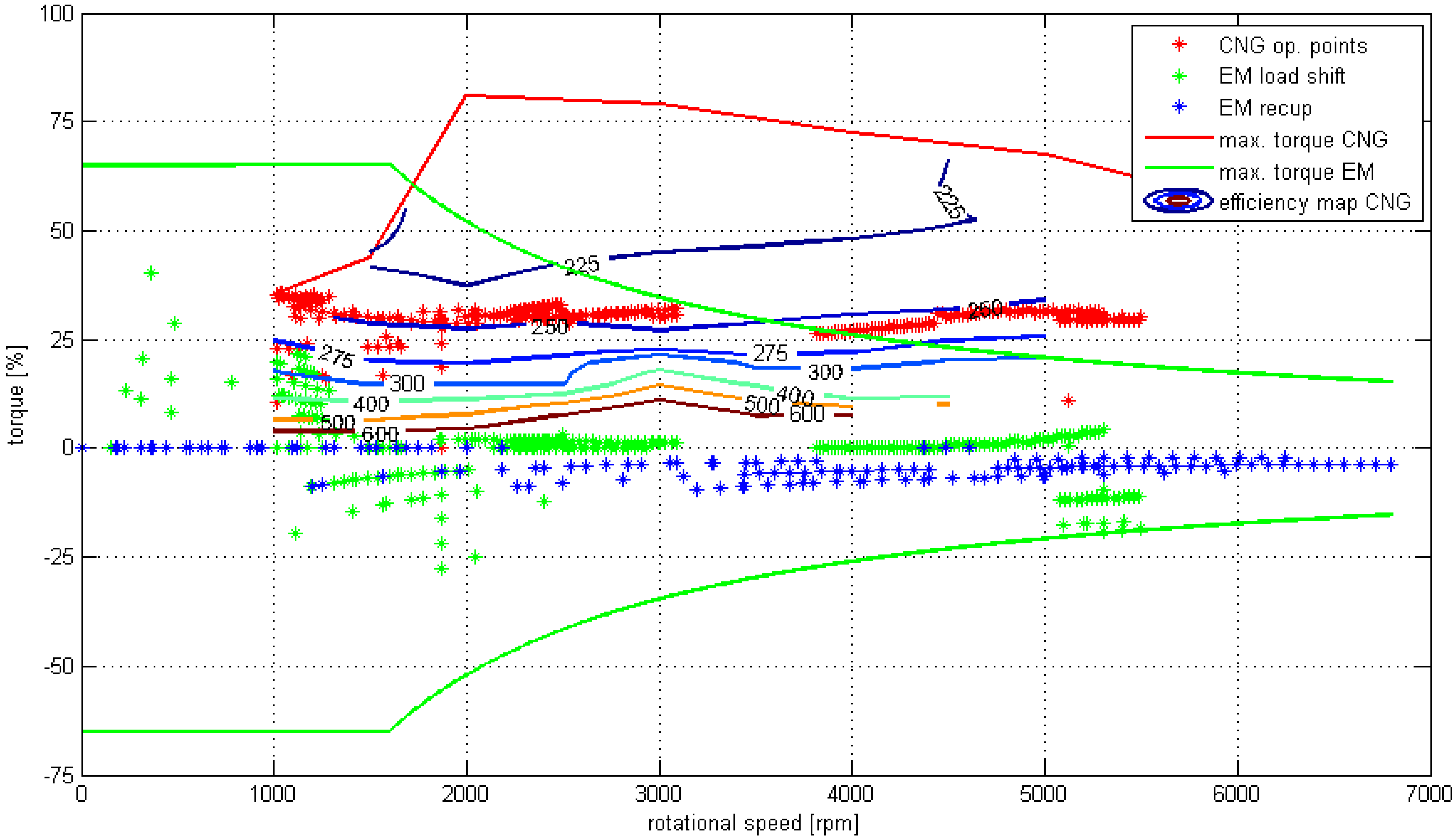
- State used for optimization: State-of-Charge, discrete
- State-of-Charge transition determines electrical engine torque
- Transition range has to be determined by required driving torque and engine torque limits
- State transition executed in all applicable gears
- Difference between required driving torque and EM torque determines ICE torque and thus the emissions
- Sum of all emissions results in driving cycle emission

Results

Electrical components



Operating points



Conclusions

- CO_2-Emissions in NEDC: ~88 g/km
  Will not be reachable in production cars due to durability, comfort and acceptance reasons
- Guidelines for static Strategies of Operation can be derived
- Forward-looking operation strategies can improve performance by discharging battery to provide storage space for recuperation

Outlook

- A project doing research on this specific car configuration is in progress at our partner institute IVK. Research is done via Simulation, test bench and real vehicle.

- Project partners

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