Safe and Efficient Electrical Vehicle

A safe Torque Vectoring function for an electrical vehicle

Volker Scheuch, Gerd Kaiser, Matthias Korte, Peter Grabs, Fabian Kreft, Frédéric Holzmann,

Intedis GmbH, Würzburg, Germany

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Agenda

A safe Torque Vectoring function for an electrical vehicle

- **Introduction**
- **Architecture**
- **Functional Safety Concept**
- **Torque Vectoring – approach and results**
- **Conclusion**

Who‘s Intedis?
Introduction

- **Joint venture**
  - Hella (Lippstadt, DE) – Electronics & lighting
  - Leoni (Kitzingen, DE) – Wiring harness systems
- **Founded in 2001, located in Würzburg, DE, ca. 4 employees**
- **Field of expertise: automotive electric/electron architectures & consultancy**
  - electromobility
  - efficient energy management
  - connectivity
  - safety
  - individuality
- **www.intedis.com**

EU funded project eFuture

„Safe and Efficient Electrical Vehicle“

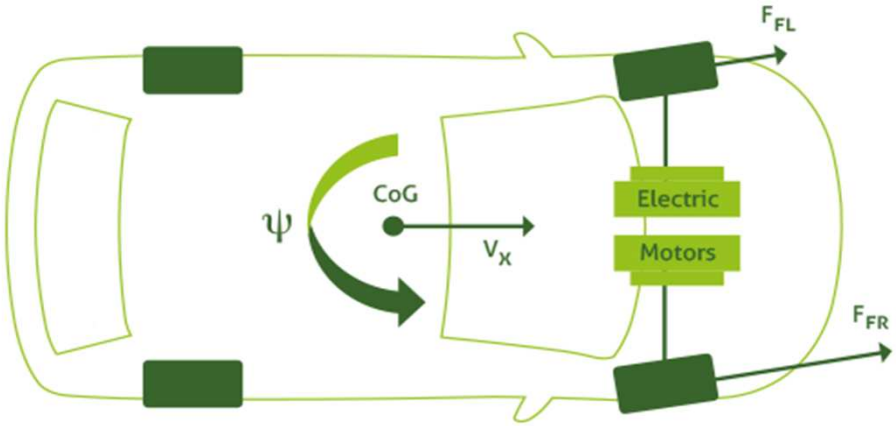
- Funded by the European Comm
- Durati (until
- Budge
- Fundir
- 6 partı 4 from 2 research institutes
- Coordinator: Intedis, Würzburg

See session 4F (project dissemination) on Tuesday, 10:35

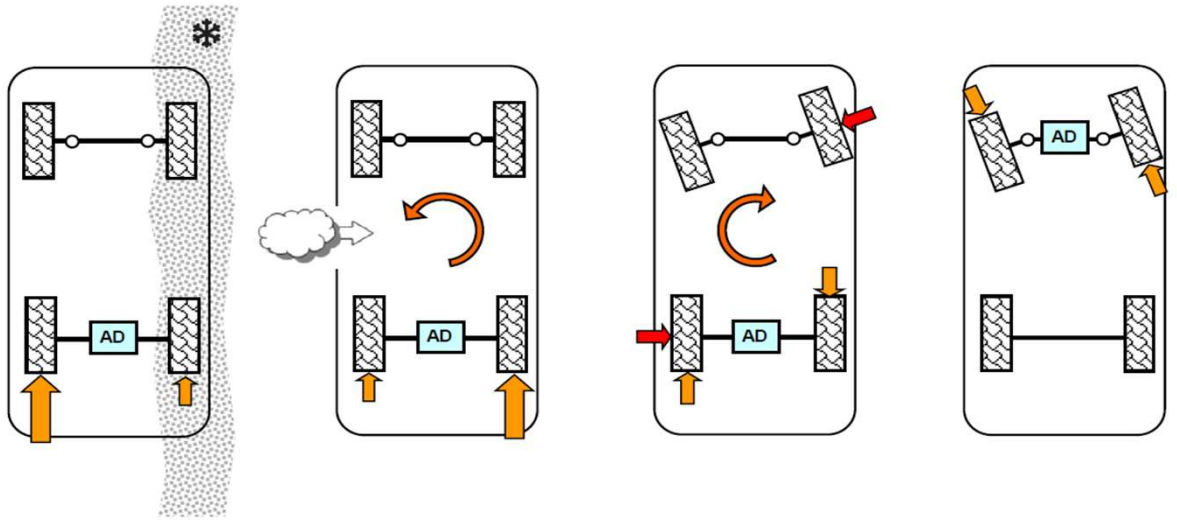
Why Torque Vectoring?

Improving driving comfort and stability

- **Two front motor drive**
  - Differential function
  - Torque distribution L ⇔ R wheel
  - Investigation agility vs. safety

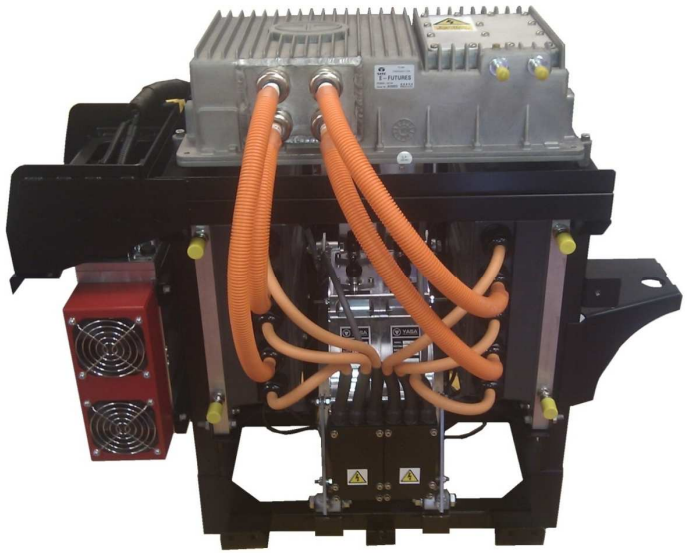


- **Torque Vectoring**
  - Improved traction
  - High comfort
  - Dynamics and safety
  - Steering support



Source: AFT

Vehicle and electric motors

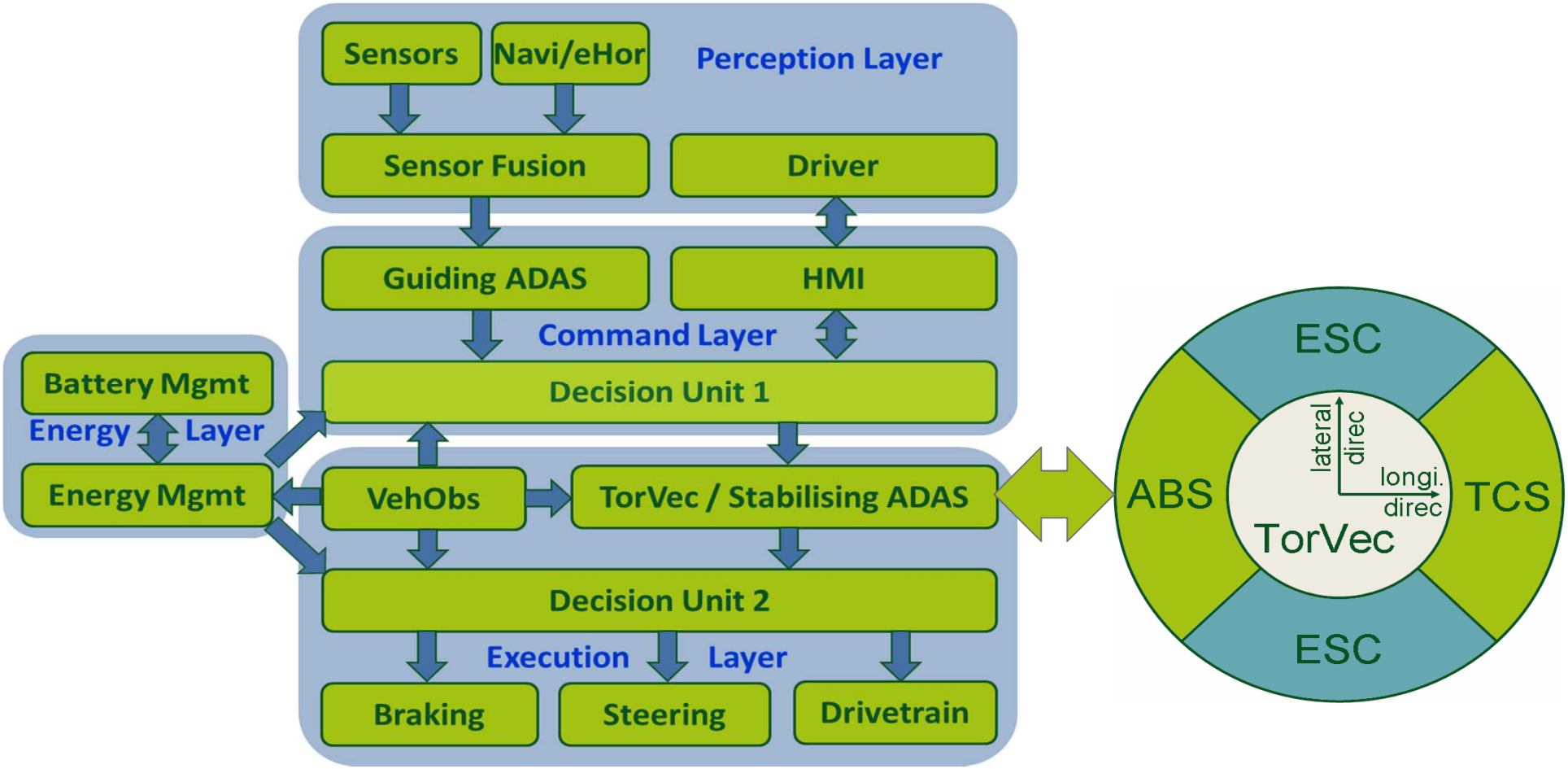


Base vehicle: Tata Indica Vista EV	
Car type	City car FEV
Maximum speed	110 km/h
Acceleration 0 – 60 km/h	9 s
Range	165 km
Charging time	8 h @ 220 V
Weight	1250 kg
Drivetrain	2 front motors
Gear box	None

Electric Motor (Yasa, UK)	
Type	PM, synch.
Peak/continuous torque	750/400 Nm
Peak/continuous power	100/55 kW
Peak system efficiency	> 95%
Motor weight	25 kg
Speed range	≤ 2000 rpm
Max. voltage	380 V

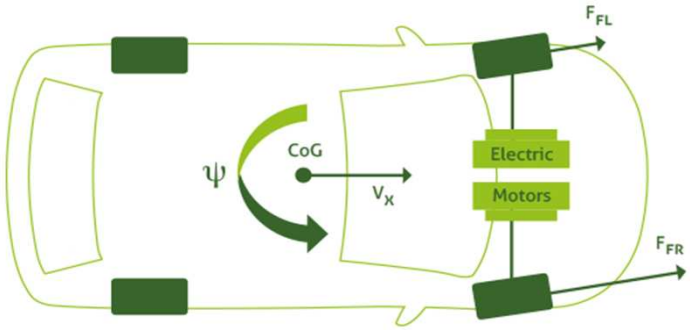
Functional architecture

Lean, scalable, domain oriented



Functional safety approach
Managing the drivetrain risks

- **Motor control only performed by software**
- **Top hazards for two (or more) motor drivetrain**
  - Unintended high acceleration
  - Unintended high deceleration
  - Unintended vehicle movement
  - **Too high or unintended yaw rate** **ASIL D**



- **Main safety requirements**
  - All input values shall be provided correctly
  - Apply same torque L & R if observer quality is too low
  - Limit yaw rate
  - Transfer to safe state if desired and actual torque differ by more than 10%
  - Transfer to safe state if one inverter status is invalid
  - Transfer to safe state for persistent divergency between intended and observed yaw rate

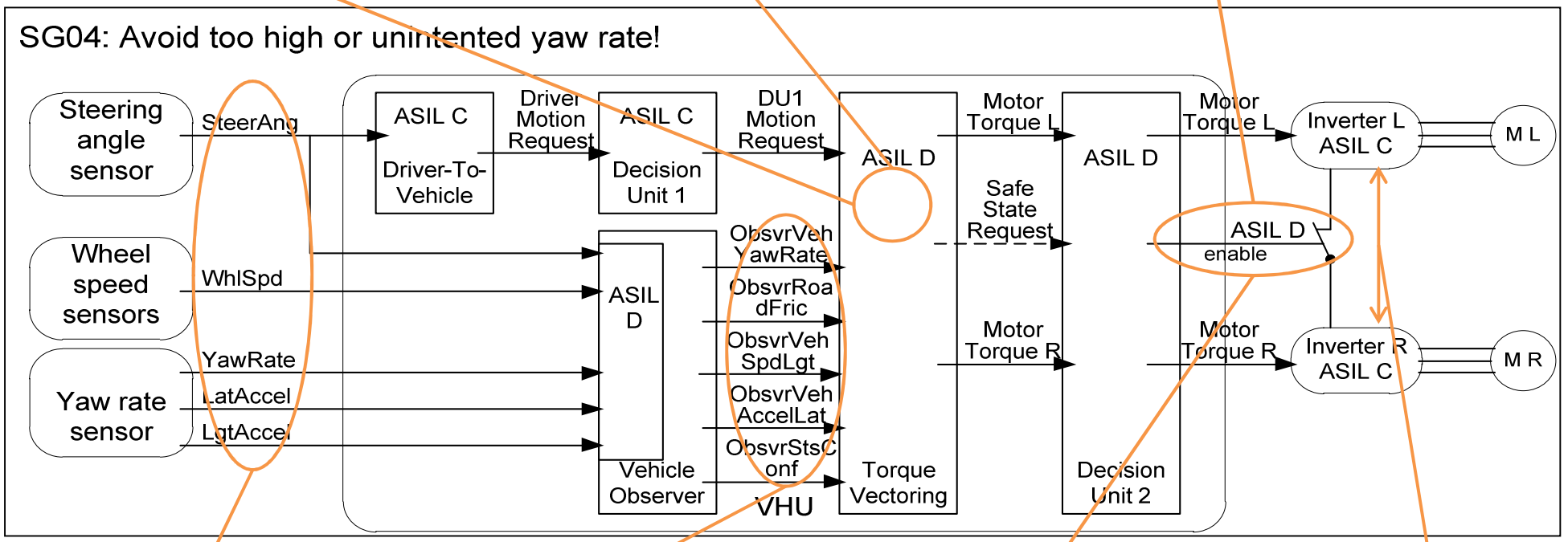
Decomposition and implementation

Functional Safety Concept

Transfer to safe state for persistent yaw rate divergency

Limit yaw rate

Transfer to safe state if desired and actual torque differ by more than 10%



All input values shall be provided correctly

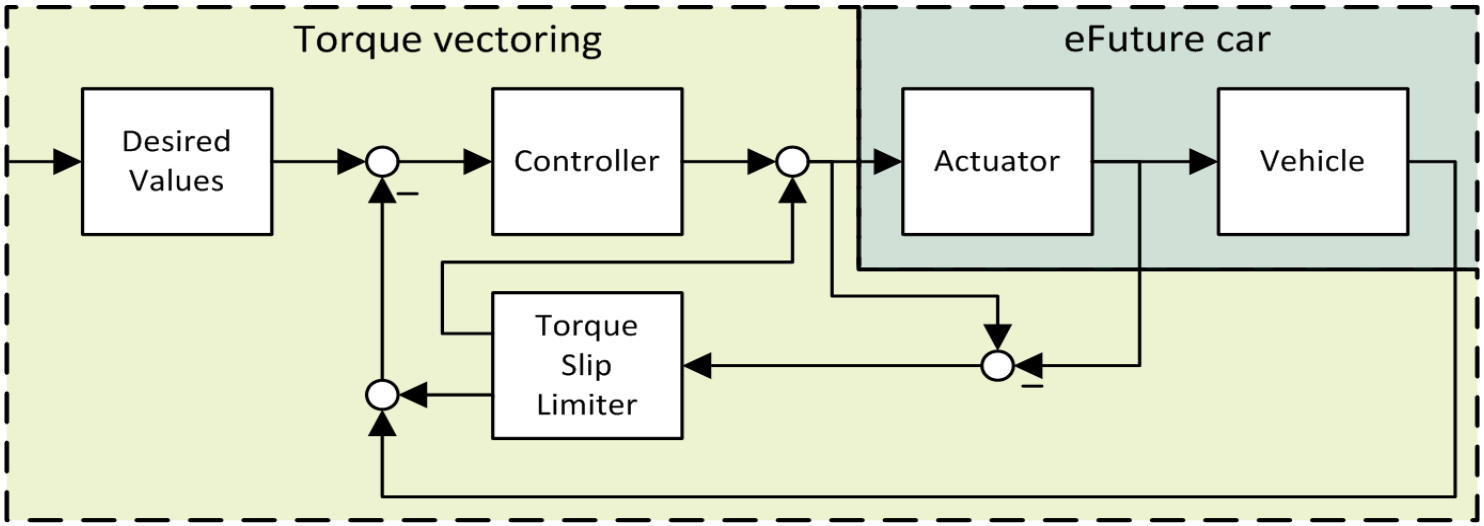
Apply same torque L & R if observer quality is too low

Transfer to safe state if one inverter status is invalid

Addition: Inverter shutdown if state is unsafe

Torque Vectoring control architecture

- TorVec attempts to keep the vehicle in a linear, controllable state
- TorVec performs accelerating, braking, yaw rate moment
- Linear parameter varying control design (LPV), tunable at different operation points
- Torque and slip limiter (TSL) takes into account physical limitations (battery, motors) and suppresses wheel spinning or blocking

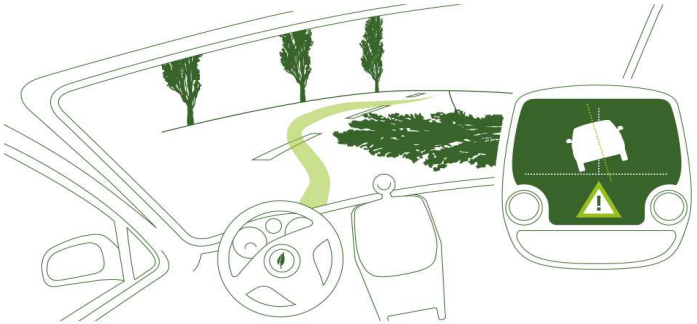


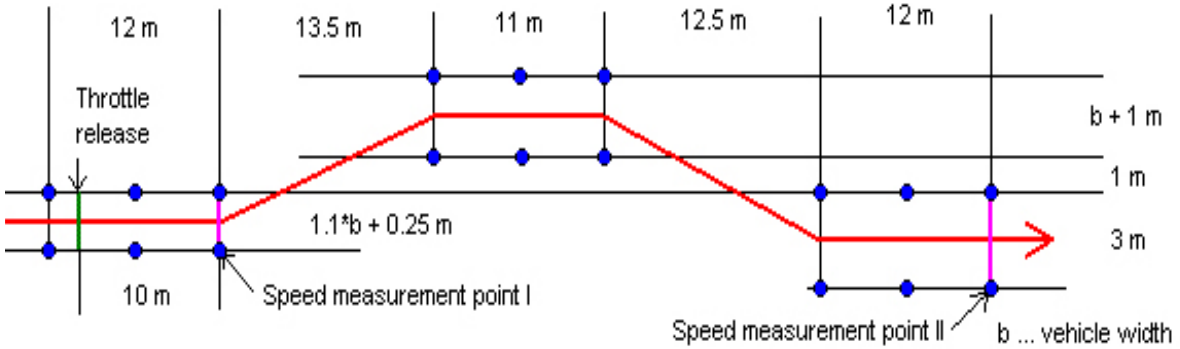
Test drive: double lane change

Torque Vectoring stabilises the vehicle

EQUAL TORQUE

TORQUE VECTORING

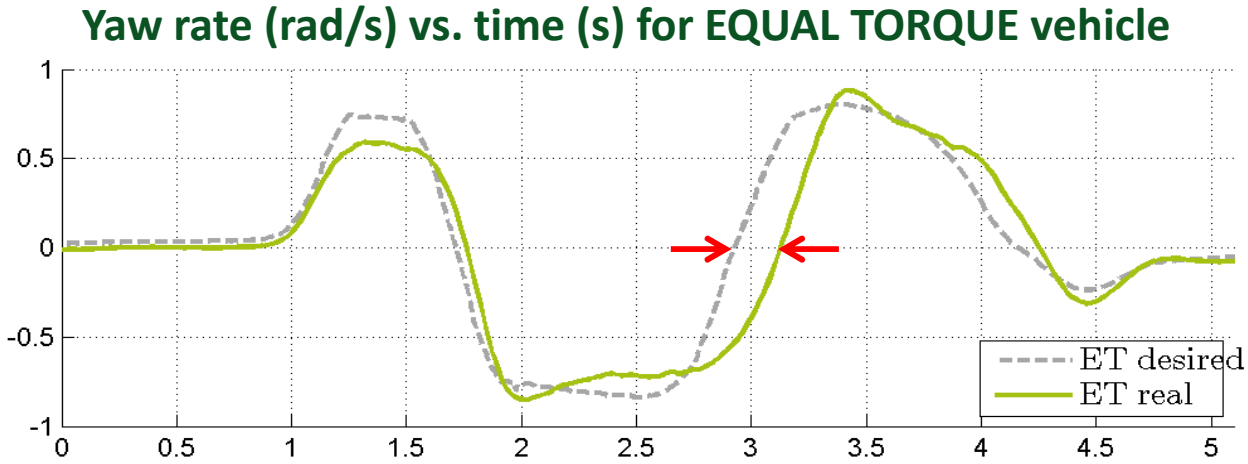




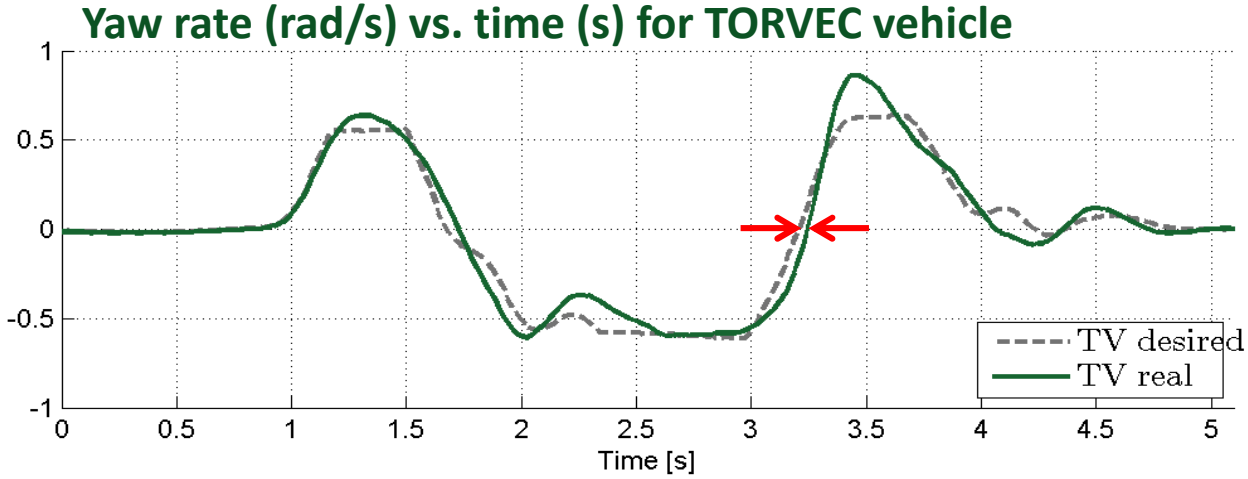
Test result: double lane change 1

Torque Vectoring stabilises the vehicle

- **Equal torque vehicle: yaw rate is delayed wrt steering request**



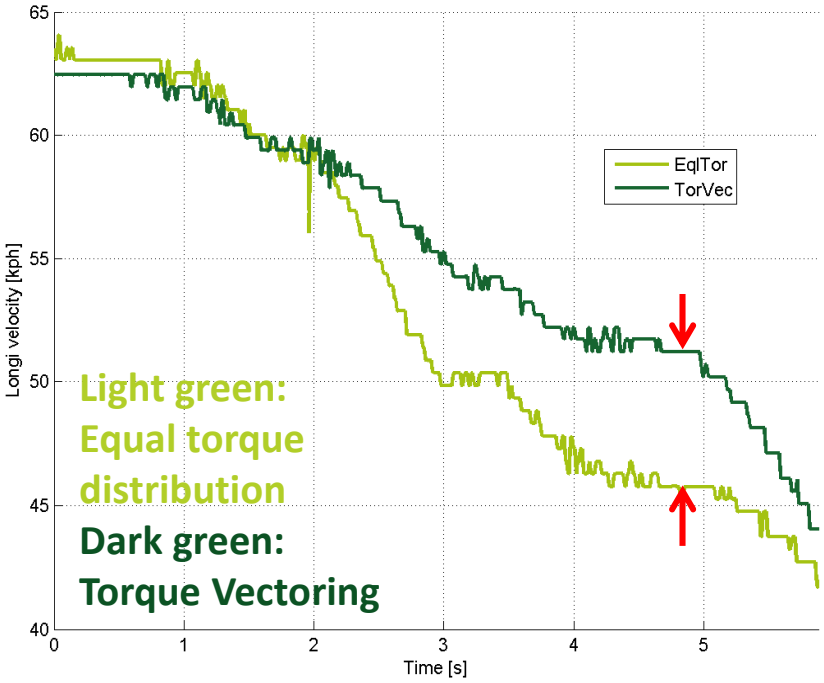
- **TorVec vehicle: yaw rate follows steering request without delay**



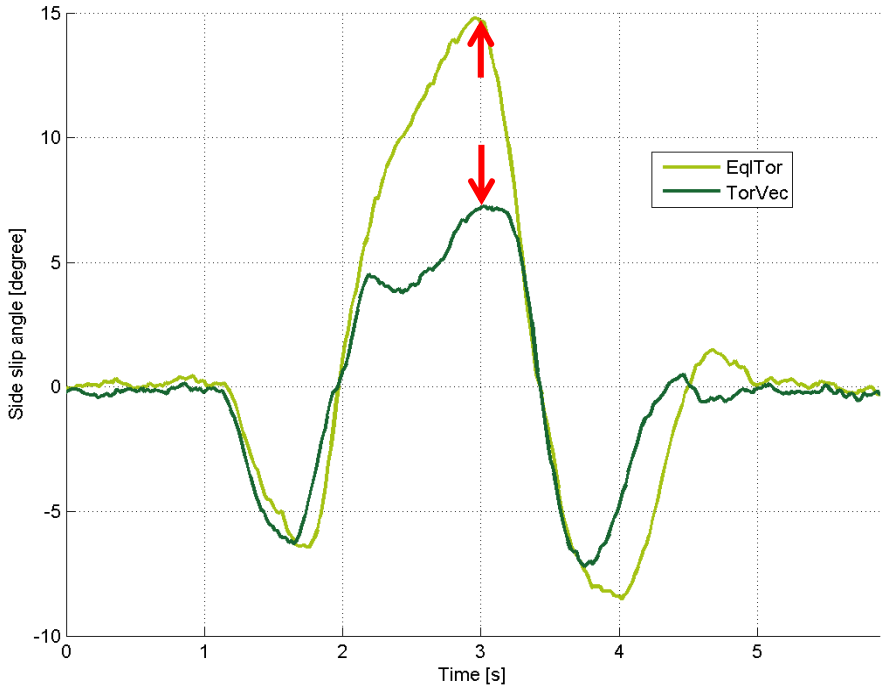
Test result: double lane change 2

Torque Vectoring stabilises the vehicle

Long. velocity (km/h) vs. time (s)



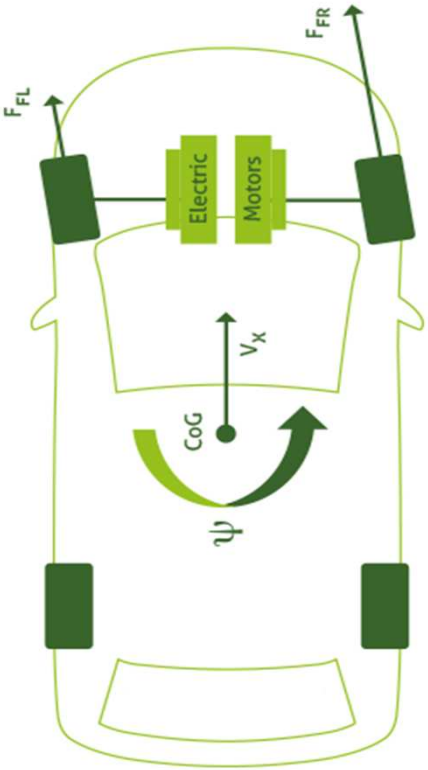
Side slip angle (deg) vs. time (s)



- The driver is able to keep a significantly higher speed in double lane change situations
- TorVec reduces the side slip angle and thus, increases directional stability

Conclusion

- The proposed functional architecture supports a simple and effective implementation of new functions and safety requirements
- The functional safety concept is suitable for dynamical functions with high risk potential
- Torque Vectoring enhances the vehicle stability in critical driving situations



- Thank you for your attention!

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