Safe and Efficient Electrical Vehicle

A safe Torque Vectoring function for an electrical vehicle

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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. 40 employees

» Field of expertise: automotive electric/electronic 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 Commission
- Duration: 3 years (until October 2013)
- Budget: ca. 7 Mio. Euro
- Funding: ca. 4 Mio. Euro
- 6 partners from 4 countries: 4 from industry, 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**

<table>
<thead>
<tr>
<th>Car type</th>
<th>City car FEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum speed</td>
<td>110 km/h</td>
</tr>
<tr>
<td>Acceleration 0 – 60 km/h</td>
<td>9 s</td>
</tr>
<tr>
<td>Range</td>
<td>165 km</td>
</tr>
<tr>
<td>Charging time</td>
<td>8 h @ 220 V</td>
</tr>
<tr>
<td>Weight</td>
<td>1250 kg</td>
</tr>
<tr>
<td>Drivetrain</td>
<td>2 front motors</td>
</tr>
<tr>
<td>Gear box</td>
<td>None</td>
</tr>
</tbody>
</table>

**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

» 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
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%

SG04: Avoid too high or unintended yaw rate!

- 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

- 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

![Graphs showing Long. velocity (km/h) vs. time (s) and Side slip angle (deg) vs. time (s)]
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!