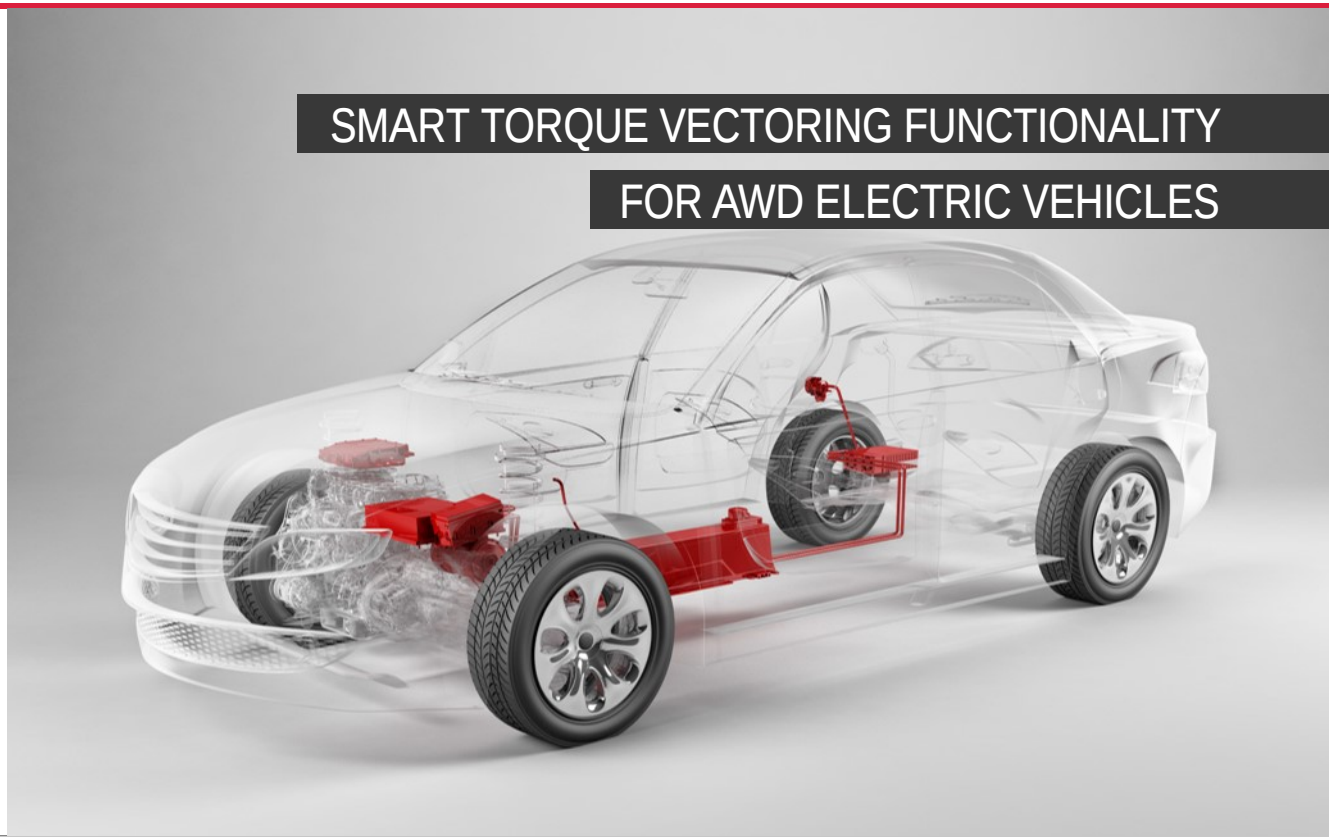
SMART TORQUE VECTORING FUNCTIONALITY FOR AWD ELECTRIC VEHICLES



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EVS30 – Electric Vehicle Symposium & Exhibition

evs 30 THE 30TH INTERNATIONAL ELECTRIC VEHICLE SYMPOSIUM & TRADE FAIR

OCTOBER 9–11, 2017 MESSE STUTTGART, GERMANY

Stuttgart, 09.10.2017
Dr. - Ing. Georg Birmes

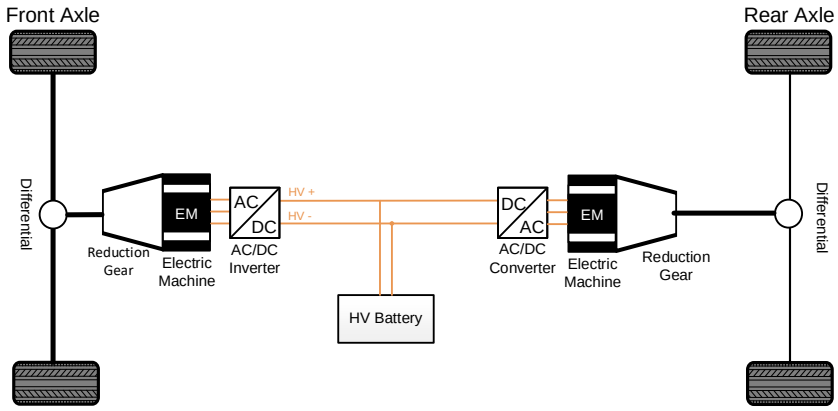
FEV

Agenda

- **Motivation**
- **Torque Split Algorithm**
- **FEV Simulation Environment**
- **Results**
- **Summary**

Motivation

An axle-split topology for electric vehicle powertrain with 2 or more electric motors has better traction performance, like conventional 4WD vehicles.



Simplified to only traction related powertrain

By introducing 2 or more independent torque source to the powertrain, there are additional degree of freedom to vary the torque distribution among the torque sources, therefore:

- Total powertrain efficiency can be optimized
- Better driving dynamic can be achieved

» How to use the new degree of freedom?

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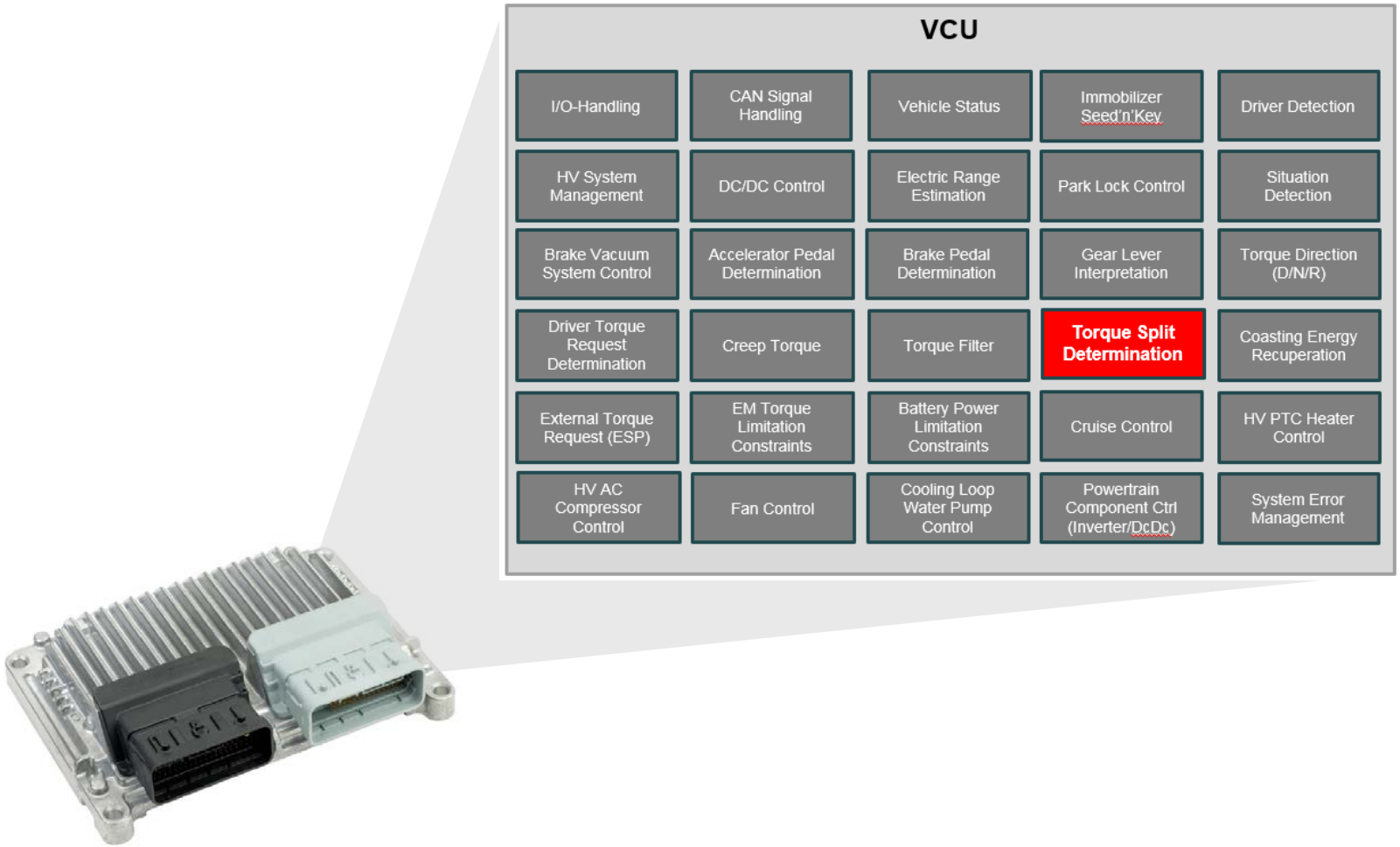
Functions allocated in VCU, Torque Path

SUMMARY OF FUNCTIONS ALLOCATED IN VCU



TORQUE PATH

Challenges:

- Efficiency
- Distribution of System Constraints (available Battery Power and EM Torque)
- Functional Safety
- Drivability

Different cases with or without sufficient power

System Efficiency Optimization

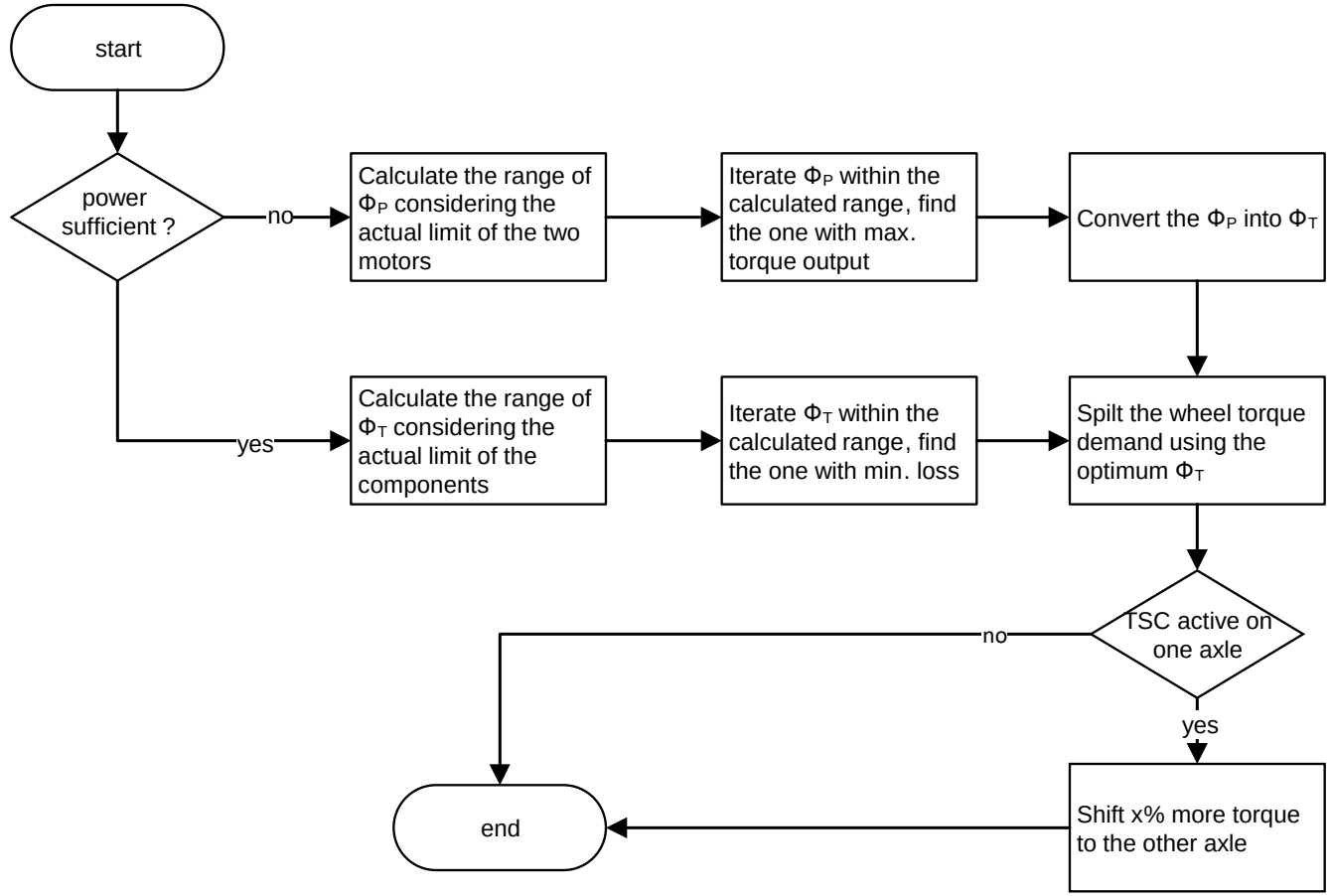
Cases with sufficient and insufficient power need to be treated differently.

- Sufficient power: wheel torque needs to be split
- Insufficient power: available power needs to be split

Case 1: sufficient power	Case 2: insufficient power
$$\Phi_T = \frac{T_{RA}}{T_{WhlReq}}$$	$$\Phi_P = \frac{P_{RA}}{P_{WhlReq}}$$
where:	*where:*
T_{RA} *is torque request to rear axle at wheel*	P_{RA} *is power request to rear axle*
T_{RA} *is total wheel torque request*	P_{WhlReq} *is total wheel power request*

Optimum torque split ratio is searched with iteration approach within the calculated boundary

FLOW CHART FOR DECIDING OPTIMUM TORQUE SPLIT RATIO



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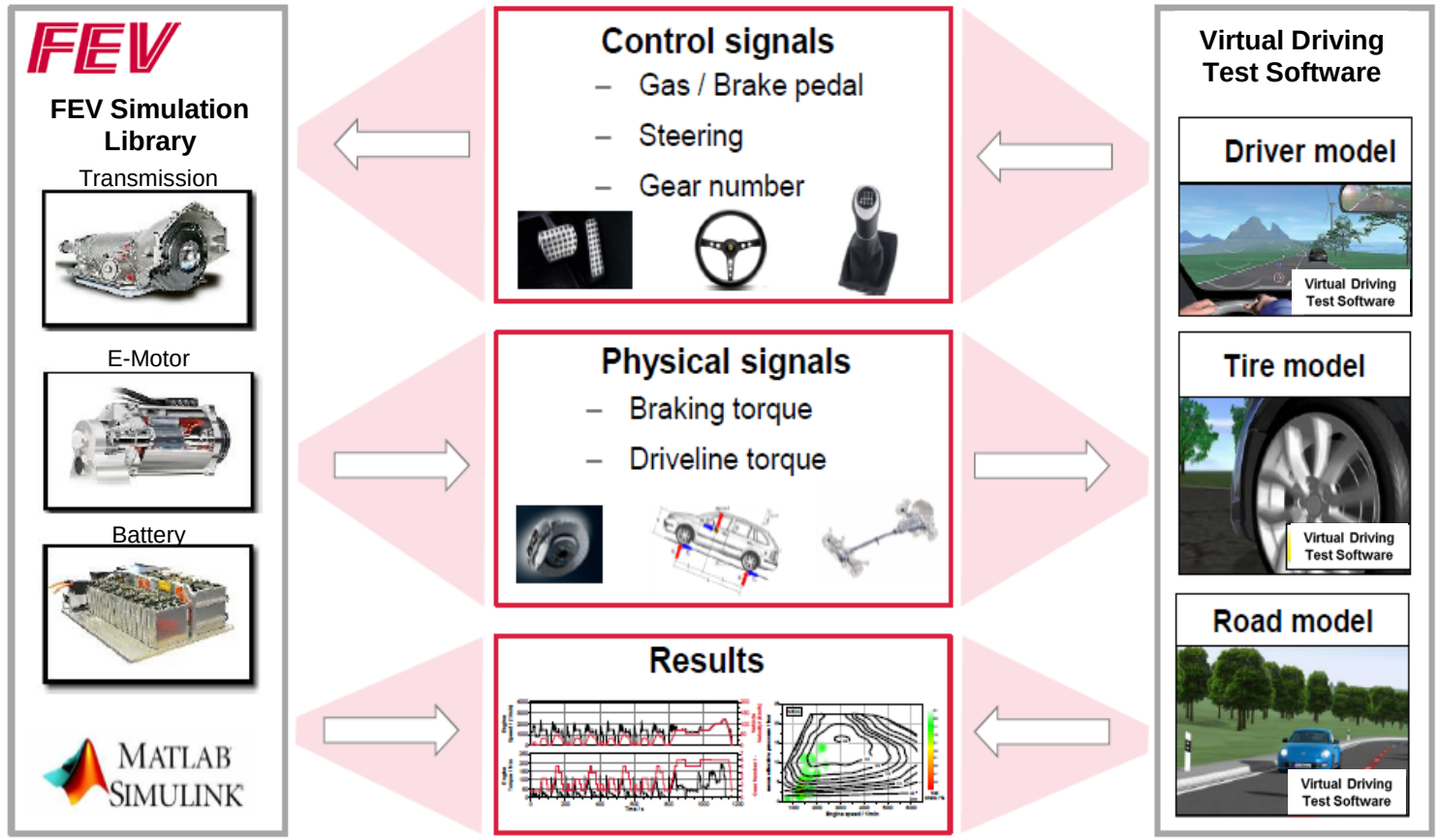
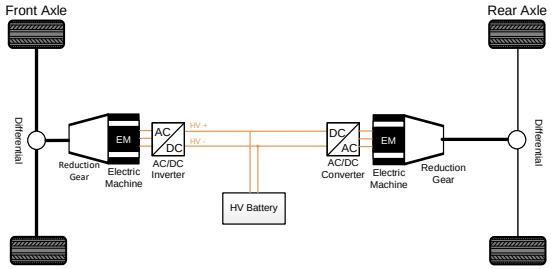
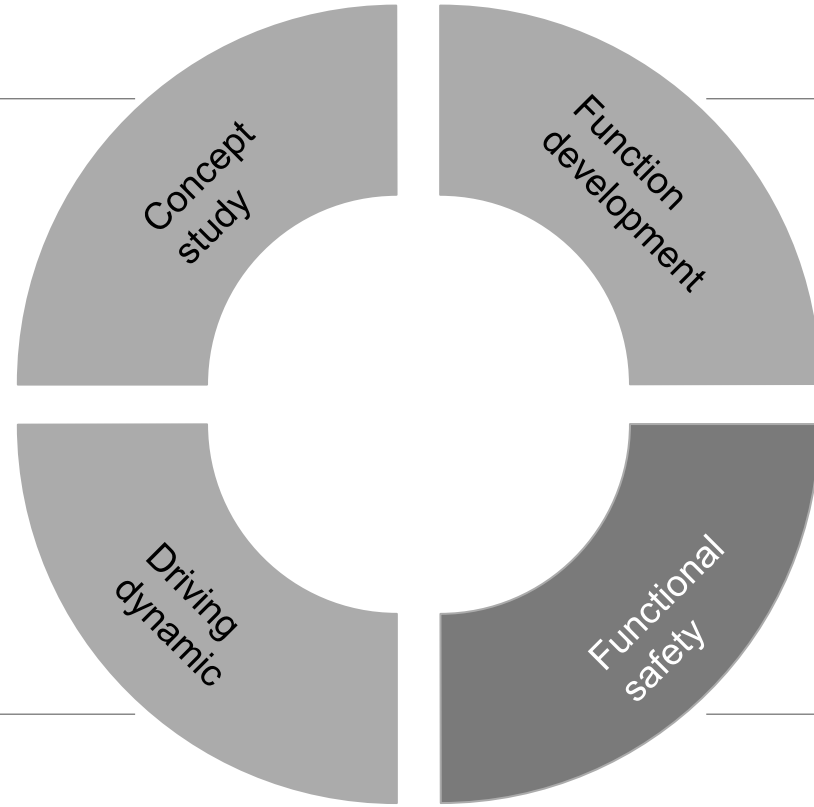
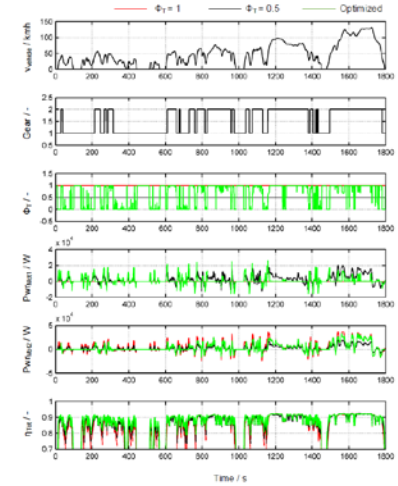
FEV simulation environment integrates sophisticated powertrain models with virtual driving test environment (dSPACE ASM or IPG CarMaker)

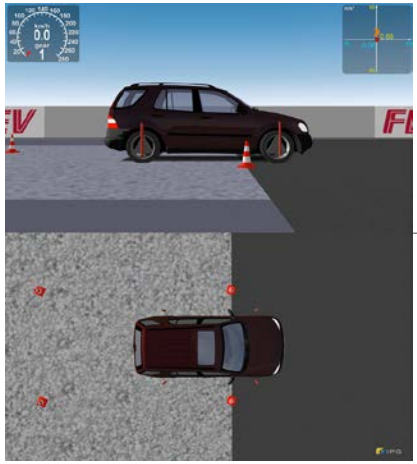


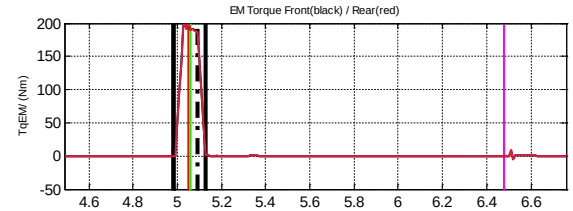
One Simulation Environment which seamless integrates the functions from different perspectives

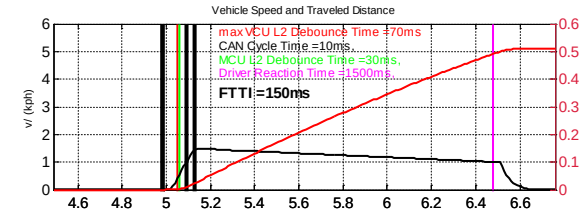












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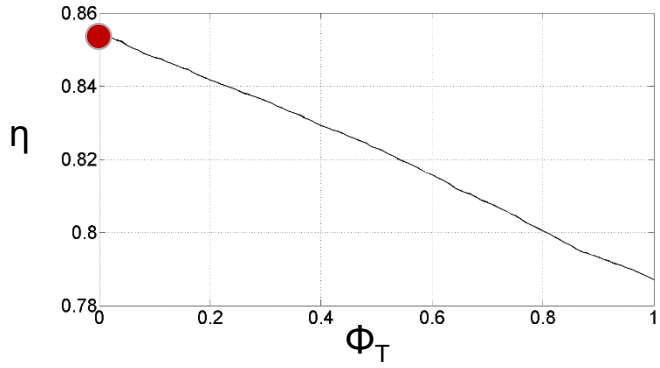
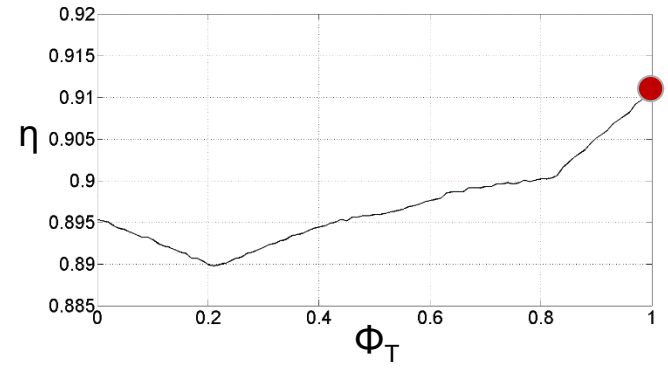
Location of optimum torque split ratio differs under different operation points

SYSTEM EFFICIENCY AT DIFFERENT OPERATION POINTS IN WLTC

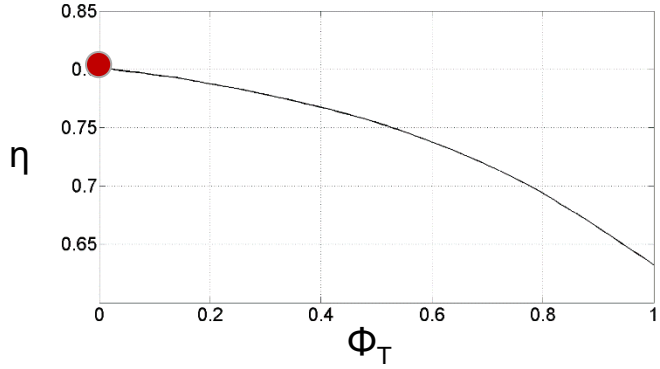
t = 60 s, v = 14.6 km/h, P = 3.9 kW



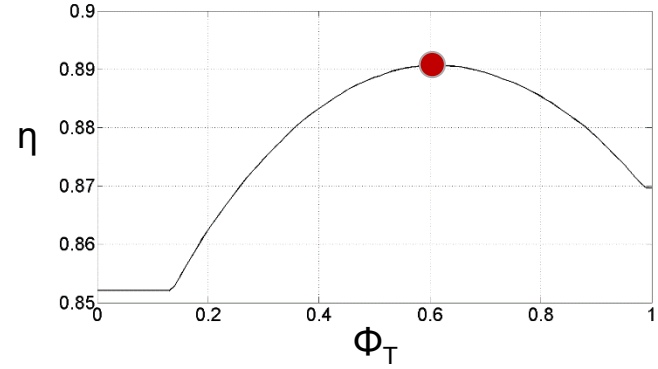
t = 230 s, v = 56.5 km/h, P = 5.3 kW



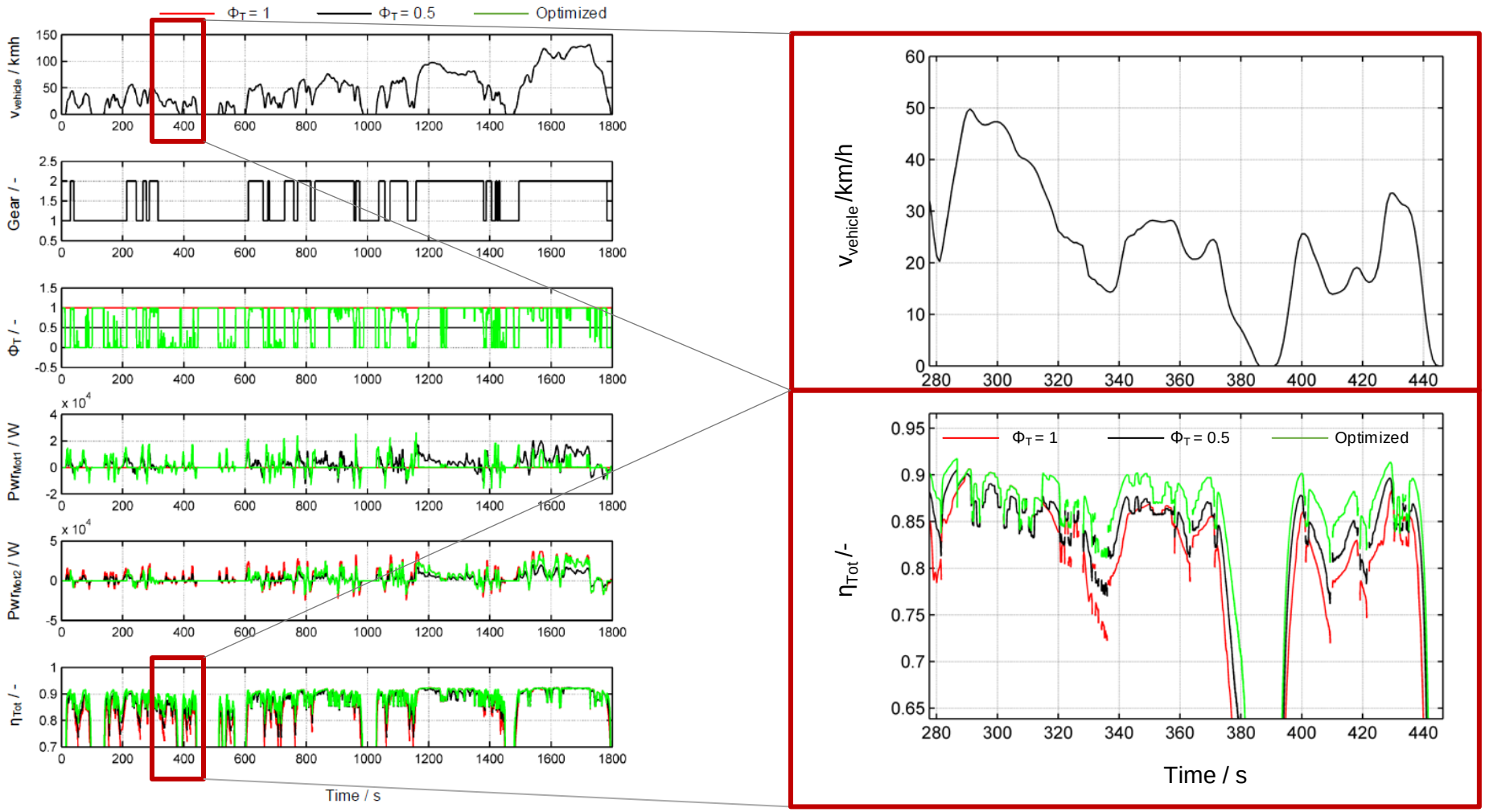
t = 440 s, v = 13.0 km/h, P = -7.1 kW



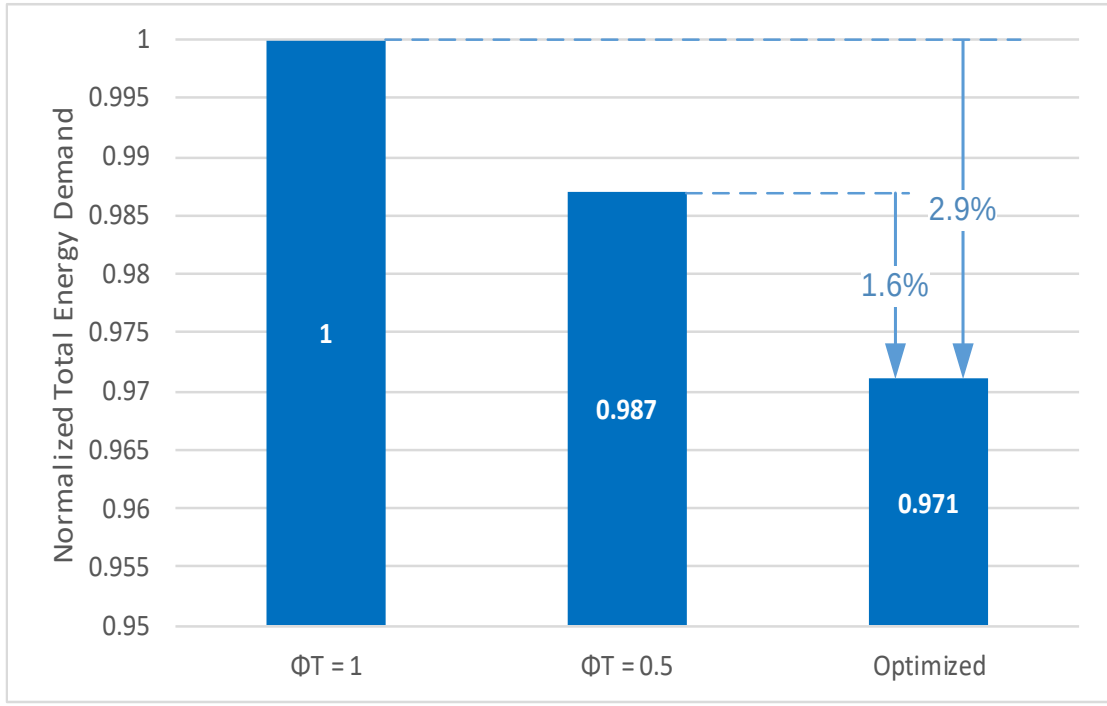
t = 1160 s, v = 48.8 km/h, P = 32.2 kW



Significant difference in system efficiency in WLTC with different torque split ratio

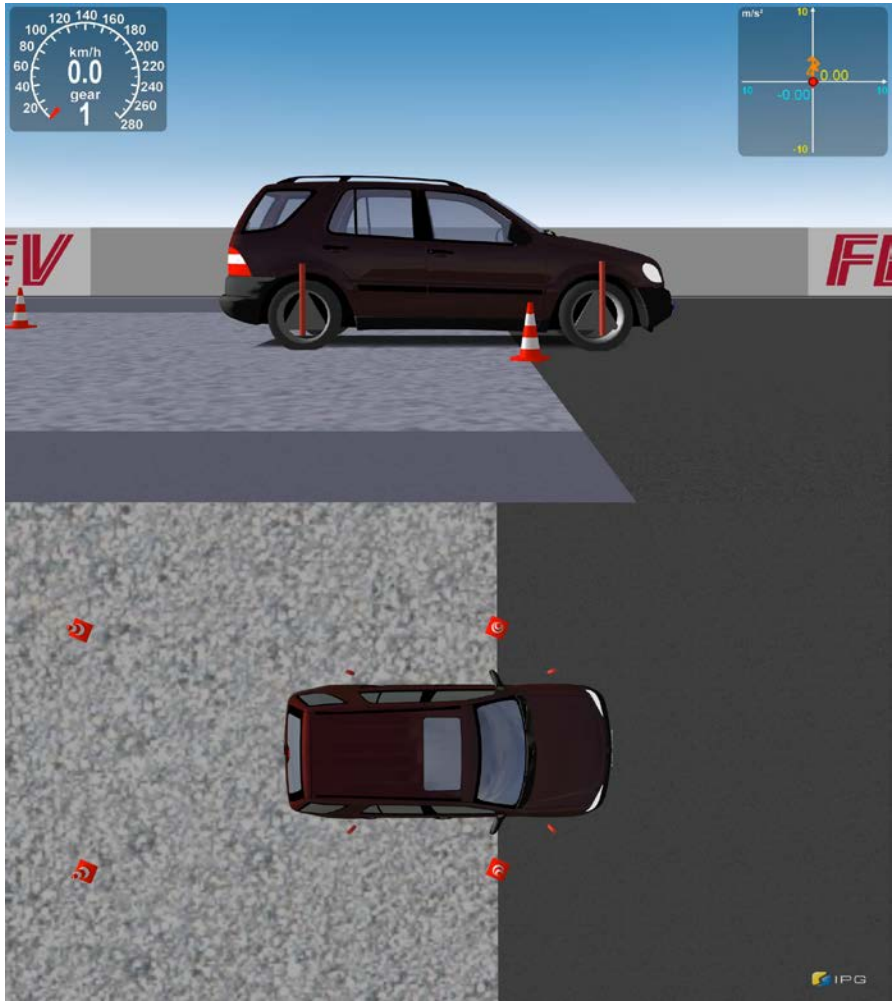


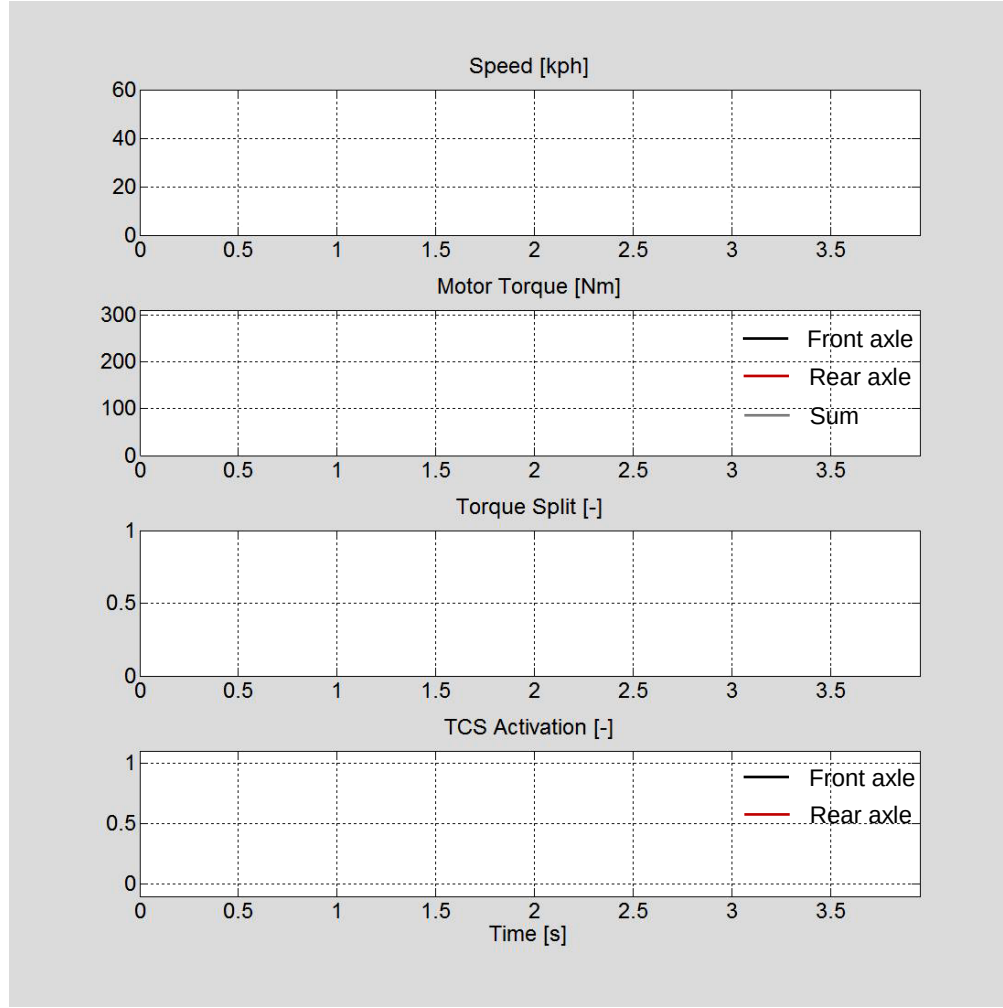
Significant energy consumption reduction is realized by optimum torque split function in WLTC



- Simulated driving cycle: **WLTC**
- **2.9 %** energy consumption can be reduced compared to single axle traction
- **1.6 %** energy consumption can be reduced compared to even traction torque distribution

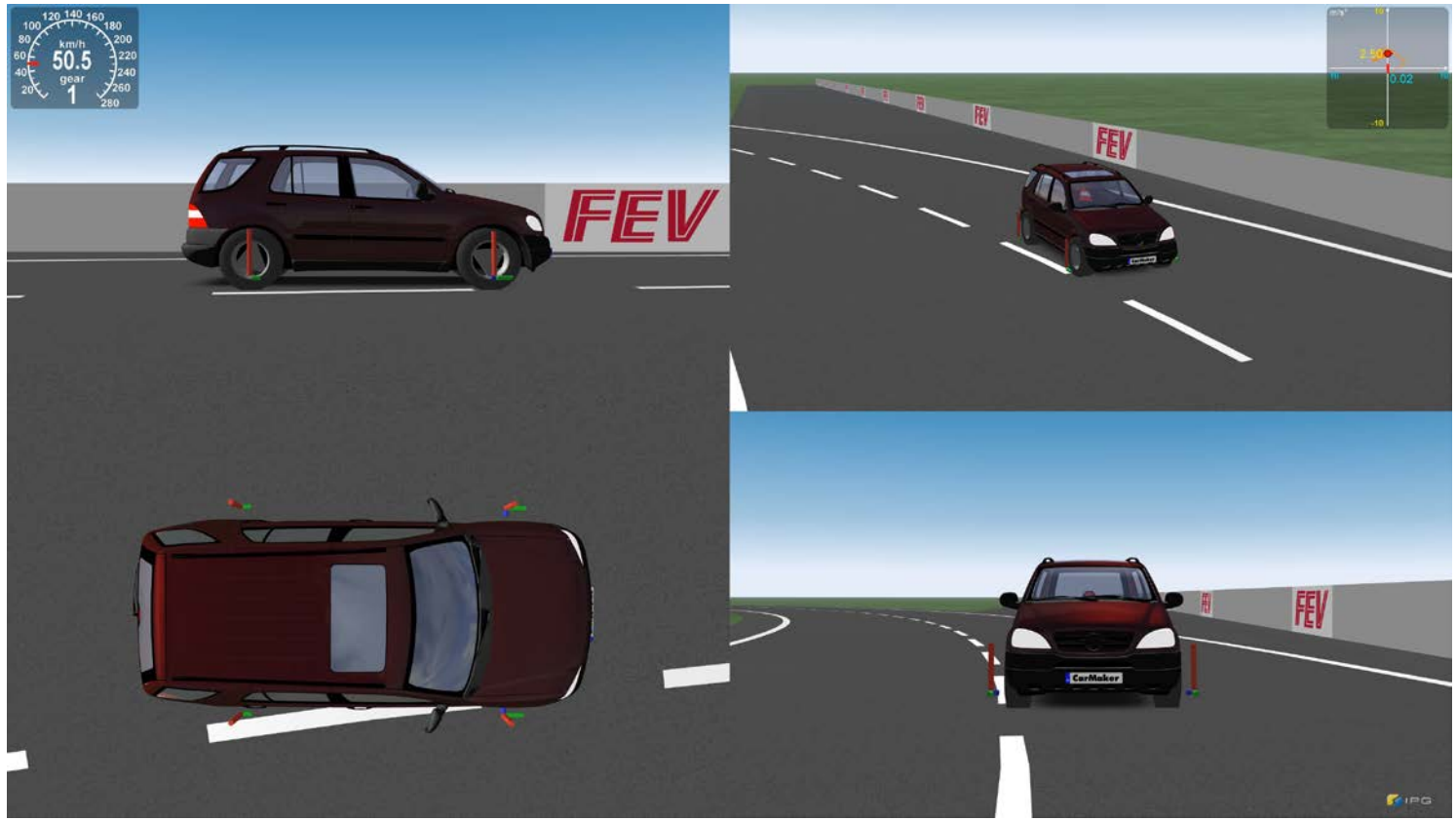
With adjusted torque split noticeable improvement of acceleration can be realized on an µ-split surface





Functional safety related topics can also be checked within the simulation environment – Controllability of Unintended Yaw

UNDERSTANDING THE SYSTEM REACTION ON FUNCTIONAL SAFETY RELATED WORST CASE STIMULI

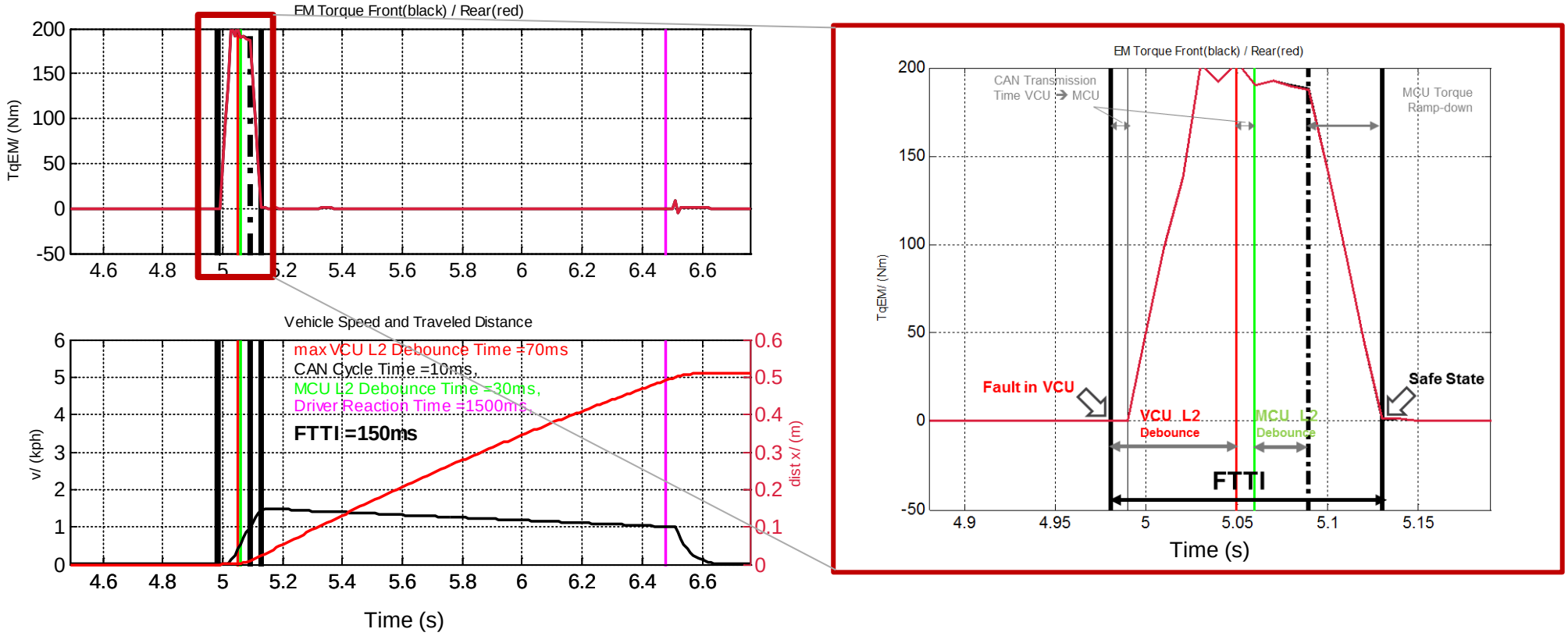


Driving Situation:

- Dry country road, 70km/h
- Cornering with 0,3g
- Apply maximum negative torque on front axle
- Fault applied for 5 Seconds with frozen driver input

Functional safety related topics can also be checked within the simulation environment – FTTI Analysis

FAULT TOLERANT TIME INTERVAL (FTTI)



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Summary & Outlook

Summary:

- FEV develops 4WD electric vehicles with axle split topology.
- Sophisticated simulation environment are built up at FEV for wide range of function developments, such as system layout, driving dynamic studies, and functional safety analysis.
- Smart torque vectoring function benefits up to 2.9 % energy consumption reduction in a WLTC simulation.
- With FEV simulation environment, a realistic FTTI is determined in very early stage of the project.

Outlook:

- Predictive functions can be introduced, so that the algorithm can react earlier to the road conditions and traffic events, such as corners and slipping roads.
- More sophisticated algorithm can be developed for powertrains with hub-motors, so that lateral dynamic can also be taken into consideration.