



fka

CREATING IDEAS &
DRIVING INNOVATIONS

High Voltage, High Risk?

Safety in 800 V+ Powertrain Systems

Laura Fautz, Meriem Balah, Gergely Bilkei-Gorzo

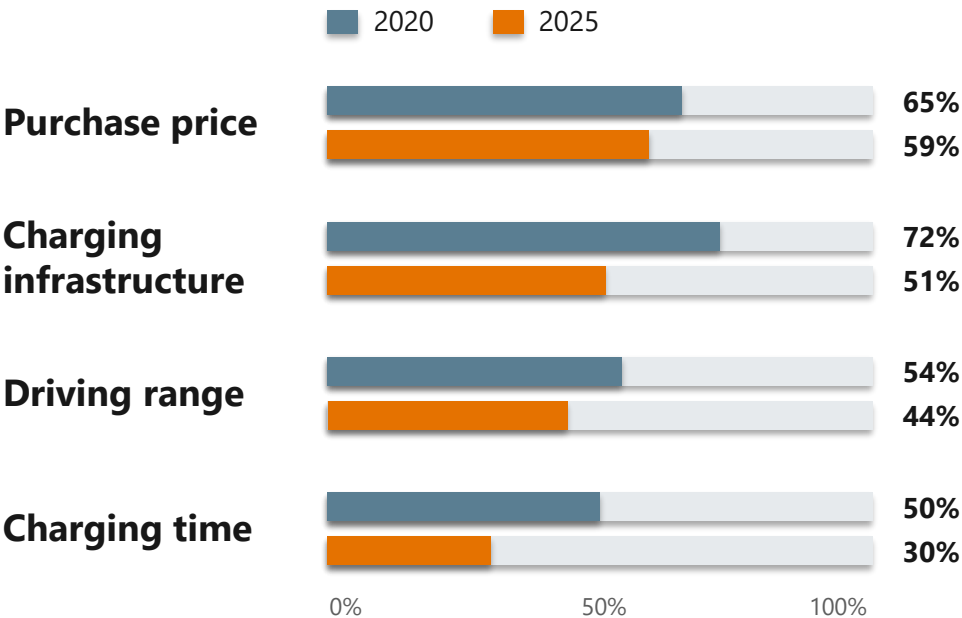
Project Motivation

Why HiVEP's E-Powertrain Development Matters



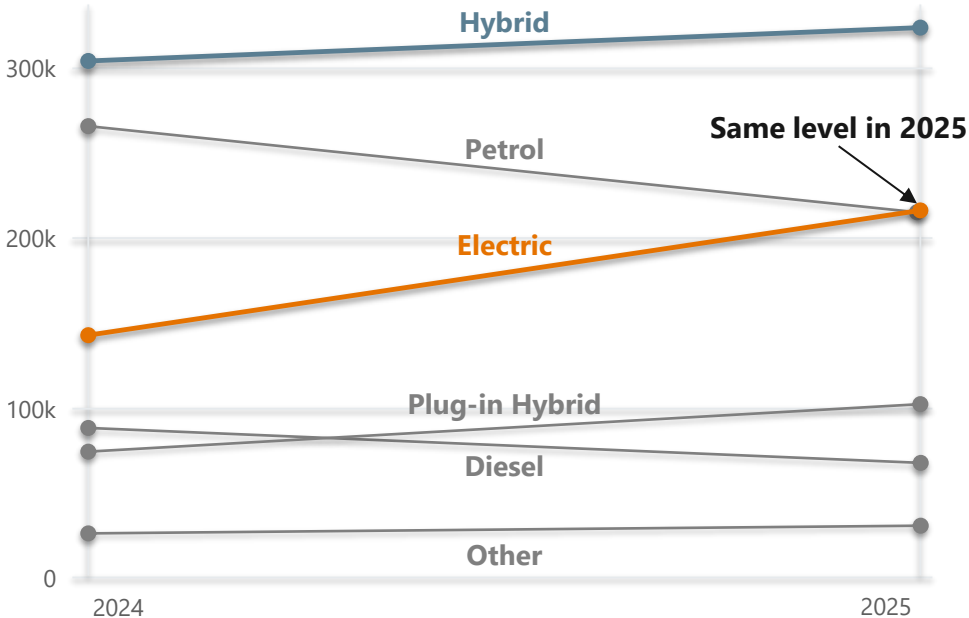
What keeps households from buying an EV?

Percentage of households stating this reason (%)



EU new vehicle registrations

Passenger cars · Dec. 2024 → Dec. 2025 · Trend overview



Innovation as a lever for greater acceptance

The EU project HiVEP advances e-powertrain technology to address concerns about driving range and charging times, helping strengthen confidence in electric vehicles.

Quellen: KfW Research, KfW-Energiewendebarmeter 2025; ACEA / Carbon Brief (EU-Neuzulassungen)

HiVEP - A Post-800 V Research Project

Powertrain Development, Functional Safety & Demonstration



GENERAL PROJECT SCOPE

POWERTRAIN DEVELOPMENT

Assess higher-voltage architectures and develop a post-800 V powertrain for the C-segment.

PROJECT GOALS

<10 min
fast charging

20%
lower cost

25%
fewer losses

V-CYCLE DEMONSTRATION

Simulation

Prototyping

Validation

DEMONSTRATOR

Validated in a full C-Segment EV from TOGG

fka PROJECT SCOPE

01

Identify Gaps in applicable Standards

... for post-800 V systems and develop recommendations to address these identified gaps.

02

Conduct Safety Analyses

... to derive safety goals and safety requirements, as well as to define component and vehicle level tests.

03

Safety Concept Development

... to ensure safe operation of the powertrain demonstrator on prototyp level.

The presentation will focus on our safety analysis results and examine how voltage level affects hazard ratings and whether higher voltage increases risk.

Methodology for Post-800 V Hazard Assessment

From Hazard Identification to Mitigation Priorities

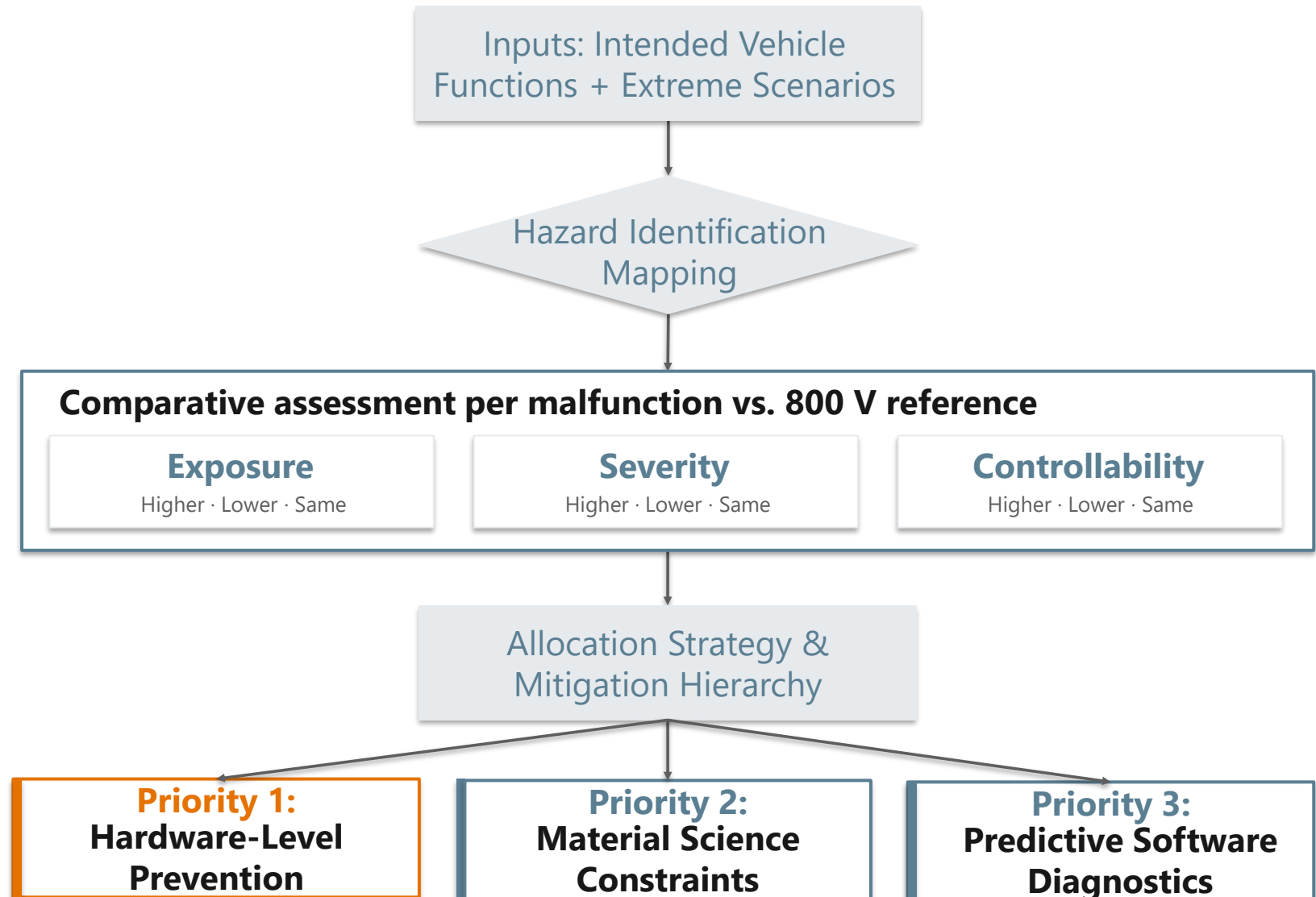
OBJECTIVE

Identification of voltage-related hazards in key components and comparison of exposure, severity and controllability between 800 V and post-800 V systems.

KEY CHALLENGES

System specifications were **unavailable**, so the assessment relied on a theoretical basis.

Electrical and functional safety address different hazard mechanisms; **both were essential** to assess post-800 V risks and support the project goal.



Main Risks occurring due to a higher Voltage Level

Hazard Mapping across Components



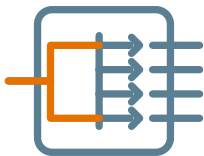
Components within the Project Scope:



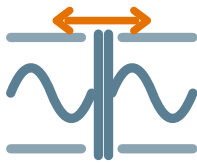
Motor



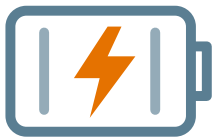
Inverter



PDU



DC/DC



Battery

Selected Hazards:



Partial Discharge



EDM and Bearing Pitting



EMI and Software Blindness



Main Risks occurring due to a higher Voltage Level

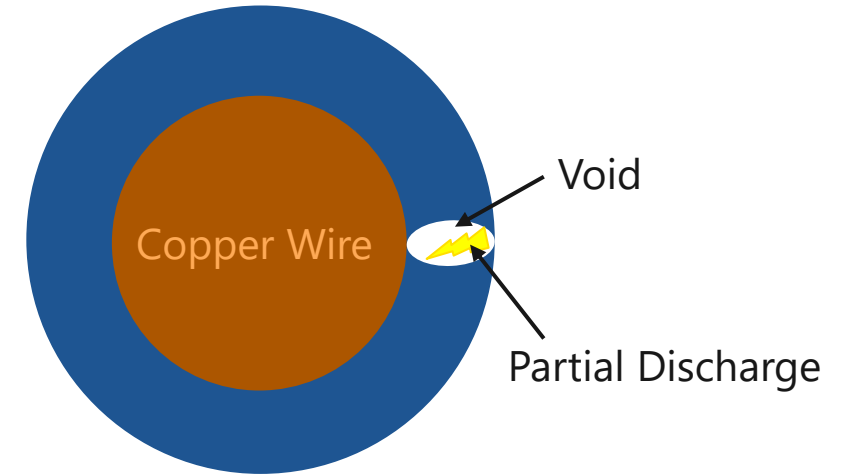
Hazard 1: Partial Discharge

Effect of Partial discharge

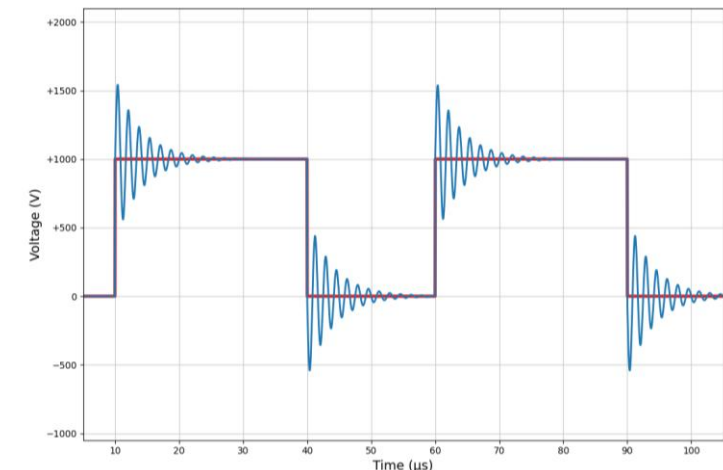
- » Post 800V architectures utilize Silicon Carbide Inverters, these can create **steeper voltage transients** ($\frac{dv}{dt}$)
- » Transients create **standing waves** at motor terminals, potentially **doubling the nominal DC-link voltage**
- » This localized electric stress can exceed the partial discharge inception voltage, **triggering continuous partial discharge**.
- » Partial discharge slowly **destroys insulation layers** and **forms carbon channels**

Consequence

- ▶ **If left unmitigated it can cause complete dielectric breakdown, leading to short circuit conditions.**



Partial Discharge in an insulated copper cable



Voltage Ringing on a Square-Wave Carrier

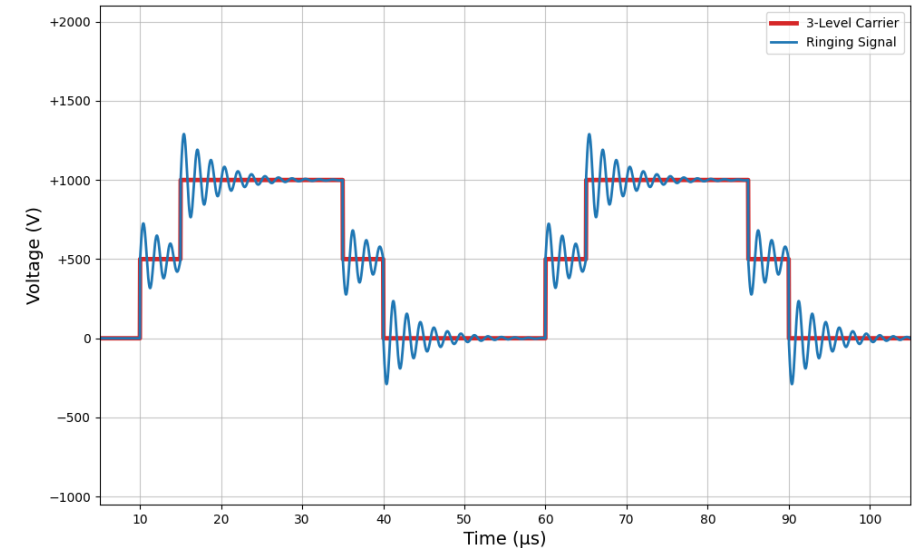


Main Risks occurring due to a higher Voltage Level

Mitigation Strategies & Risk Level: Partial Discharge

Mitigation Strategies

1. Use **insulation that is partial discharge resistant** at the expected peak voltages
2. **Minimize cable length** between inverter and motor
3. Use **soft switching** or **multi-level inverter topologies** to limit voltage transients ($\frac{dv}{dt}$)



Voltage Ringing on a Multi-Level Carrier

Risk
Assessment

EXPOSURE



same

CONTROLLABILITY



lower

SEVERITY



same

... compared to a 800 V System

Main Risks occurring due to a higher Voltage Level

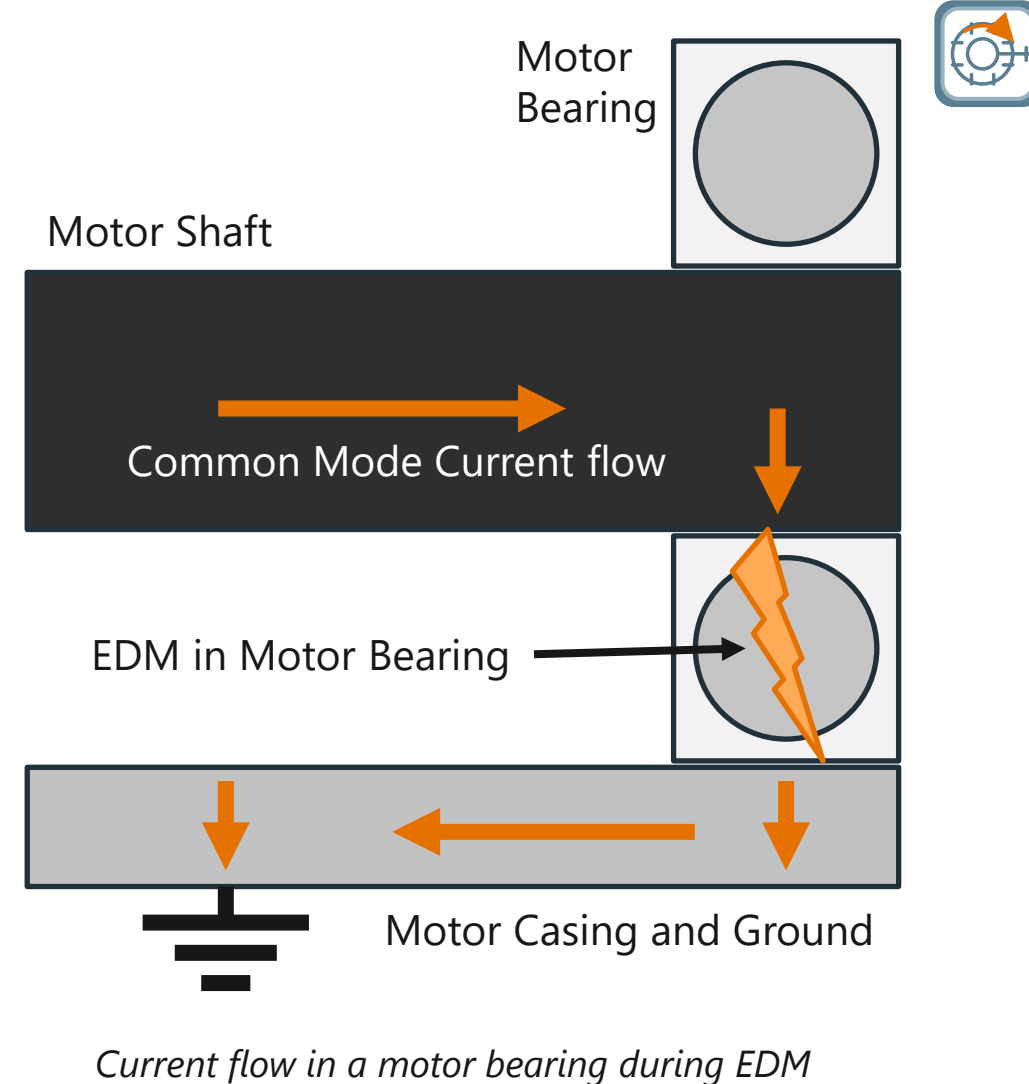
Hazard 2: EDM and Bearing Pitting

Effect of EDM and Bearing Pitting

- » The switching transients of Silicon Carbide inverters generate **high-frequency common-mode voltage**
- » This voltage capacitively couples to the motor shaft and **discharges through the bearing grease** to the ground
- » **Elevated voltage levels increase this common mode voltage**, accelerating **damage through Electrical Discharge Machining**

Consequence

- ▶ **If progressive pitting is left unmitigated, it leads to vehicle vibration and ultimately a mechanical lockup.**



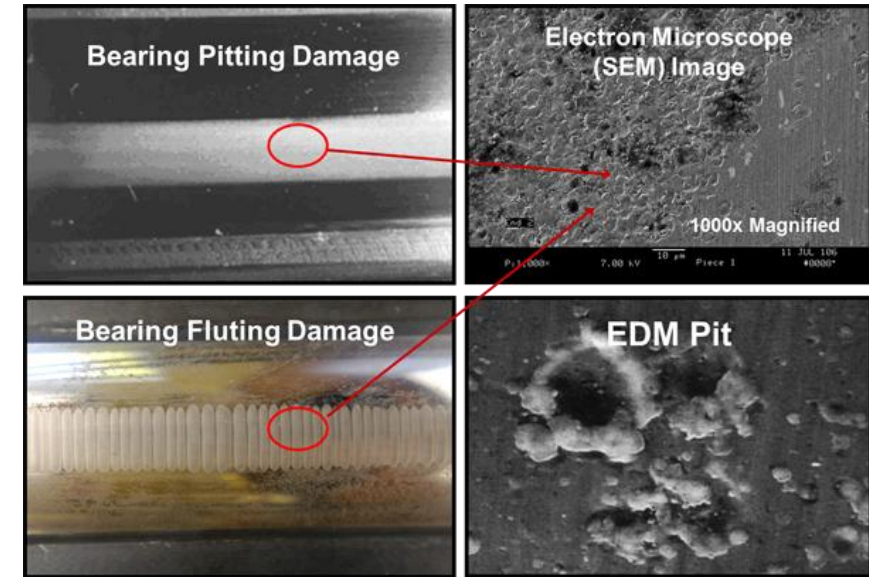
Main Risks occurring due to a higher Voltage Level

Mitigation Strategies & Risk Level: EDM and Bearing Pitting



Mitigation Strategies

1. Reducing voltage transients (dv/dt) via **soft switching** or **multi-level topologies**
2. Using **insulated bearings**, like ceramic or hybrid insulated bearings
3. Adding **active shaft grounding rings** to the motor shaft to prevent discharge over motor bearings



Effect of EDM on bearing surfaces

Risk
Assessment

EXPOSURE



same

CONTROLLABILITY



lower

SEVERITY



same

... compared to a 800 V System

Main Risks occurring due to a higher Voltage Level

Hazard 3: EMI and Software Blindness

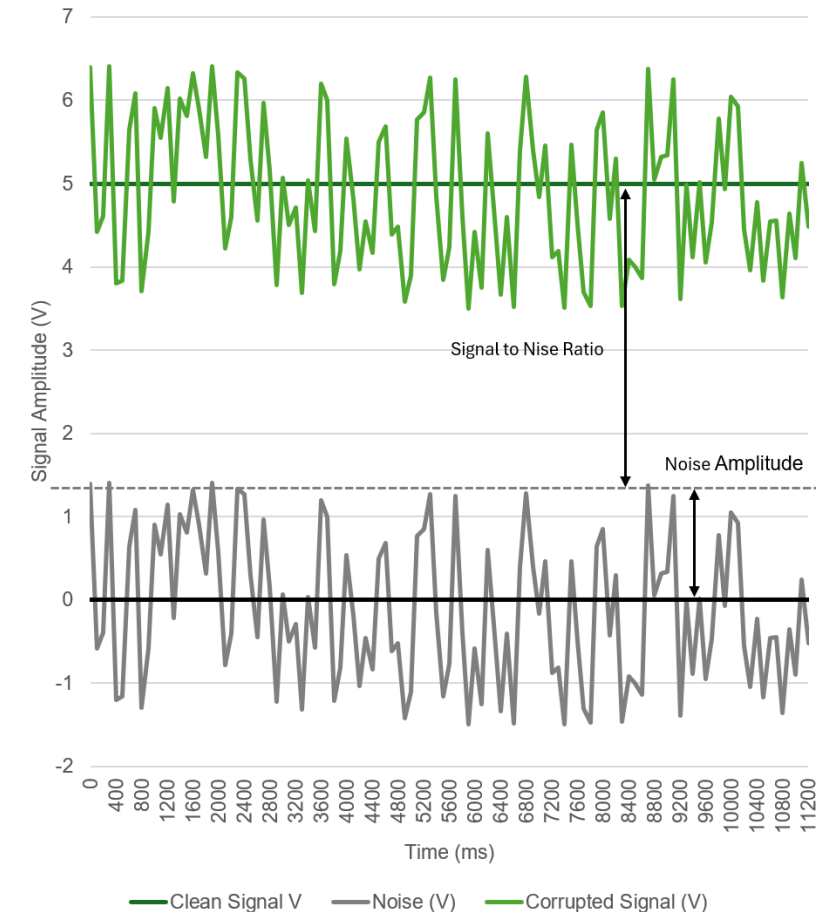


Effect of EMI and Software Blindness

- » Steeper voltage ($\frac{dv}{dt}$) and current ($\frac{di}{dt}$) transients in post 800V power nets generate **higher electromagnetic interference with wider bandwidth**
- » This **increased noise couples capacitively or inductively** into neighboring signal lines and low voltage control networks
- » Due to the distorted sensor values the **system might be unable to detect the necessity of protective derating or shutdown**

Consequence

- ▶ **Disrupted control loops, unintended/missed emergency shutdown**



Signal to Noise Ratio



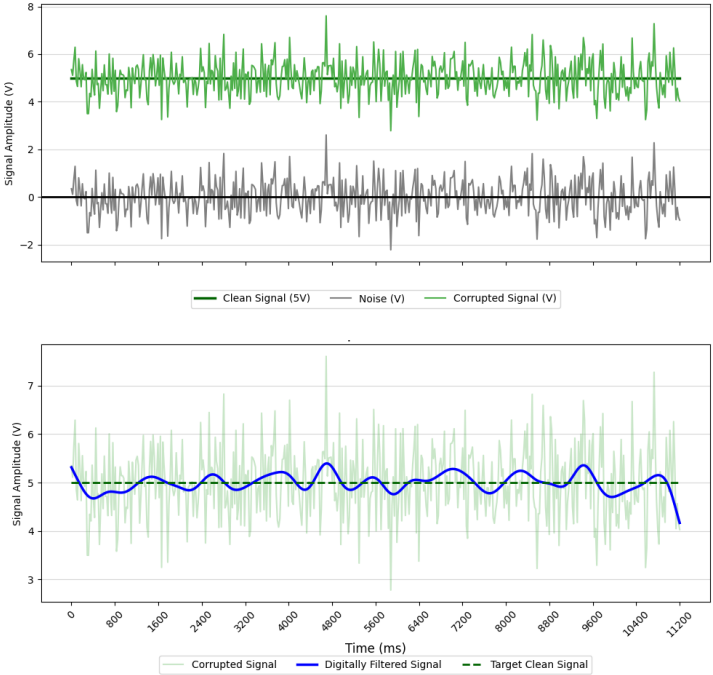
Main Risks occurring due to a higher Voltage Level

Mitigation Strategies & Risk Level: EMI and Software Blindness



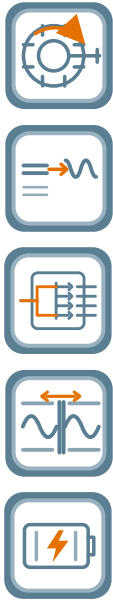
Mitigation Strategies

- 1. Use **hardware override mechanisms** next to software detection
- 2. **Active digital filtering** can improve signal quality
- 3. **Isolate sensitive lines** from high voltage switching components, cables and busbars



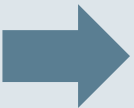
Original Noisy Signal

Effect of a Lowpass Butterworth Filter



Risk
Assessment

EXPOSURE



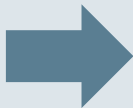
same

CONTROLLABILITY



lower

SEVERITY



same

... compared to a 800 V System

Main Risks occurring due to a higher Voltage Level

Summary of the Safety Analysis conducted



Exposure & severity unchanged; reduced controllability for occurring malfunctions.

EXPOSURE

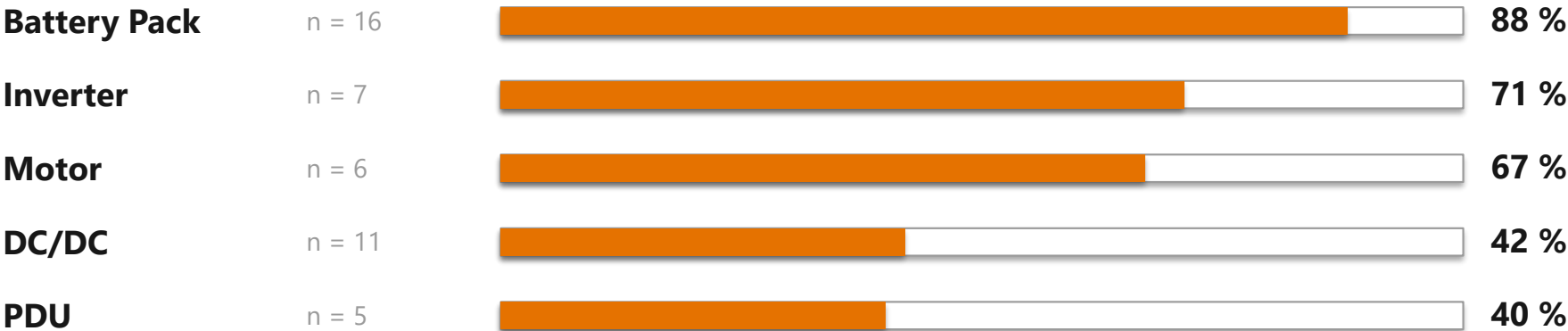
100 % unchanged compared with an 800 V system
across all five system components.

SEVERITY

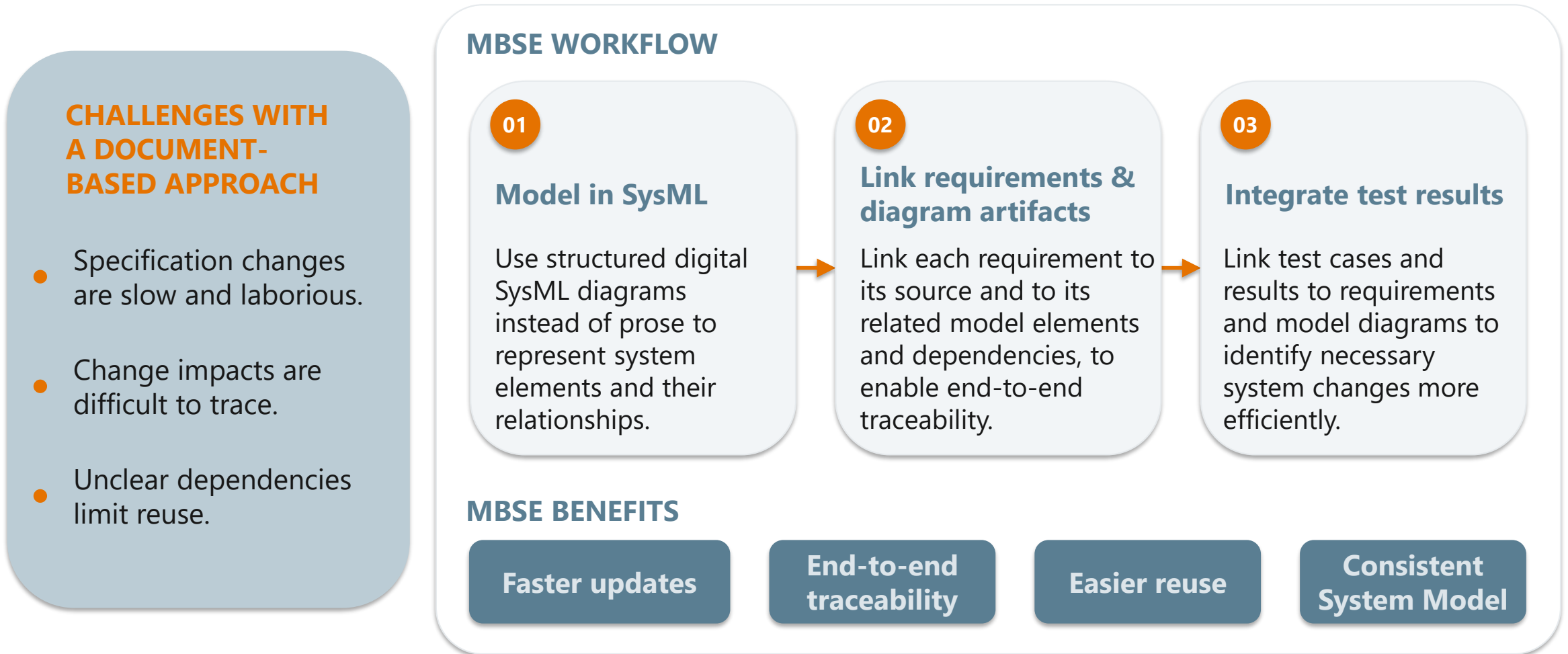
100 % unchanged compared with an 800 V system
across all five system components.

Reduced controllability compared with an 800 V powertrain

Share of identified potential malfunctions

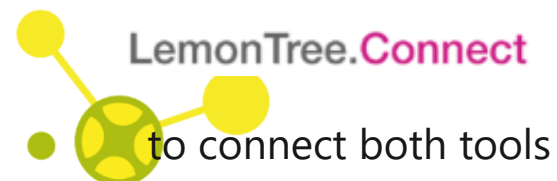


~ **66%**
of malfunctions
have reduced
controllability
vs. 800 V



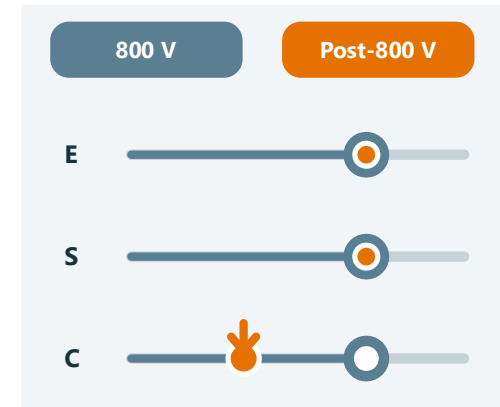
The next project step will explore how the benefits of MBSE can be applied to functional safety.

MBSE System Model in Modelling Tool



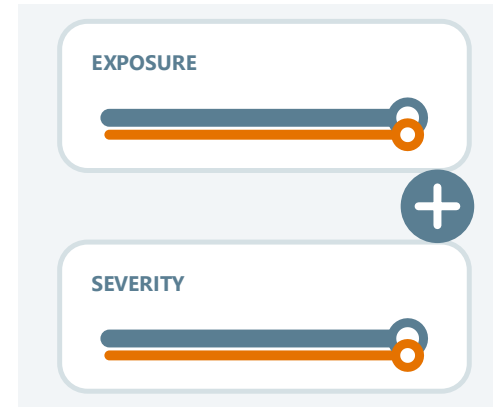
High Voltage, High Risk?

Key Takeaways for Safety in 800 V+ Powertrain Systems



Voltage level affects controllability only

Controllability was lower than in the 800 V baseline for ~66% of identified malfunctions. This should guide safety concept development.



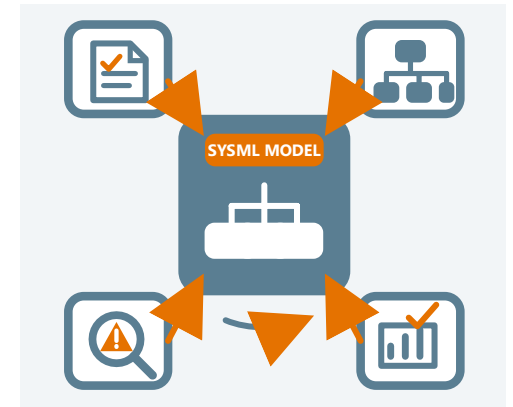
Exposure and severity remain unchanged

Across all five assessed components, higher voltage did not change exposure and severity ratings compared with 800 V.



Safety assurance is not the bottleneck

Technical mitigation options are available, the main challenge is component availability and cost, particularly where standards are not yet established.



MBSE enables faster changes and reuse

Linking models, requirements and test results improves traceability. Potential benefits for safety assessment.

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Thank you for your attention!

 **Laura Fautz, M.Sc.**

Manager MBSE and Functional Safety

 +49 241 8861 126

 laura.fautz@fka.de

 <https://www.linkedin.com/in/laura-fautz-276279209/>

