International Conference on DC Microgrids

# Evaluation of Semiconductor-Based Isolation for Electric Vehicle Chargers in DC Microgrids

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# INTRODUCTION

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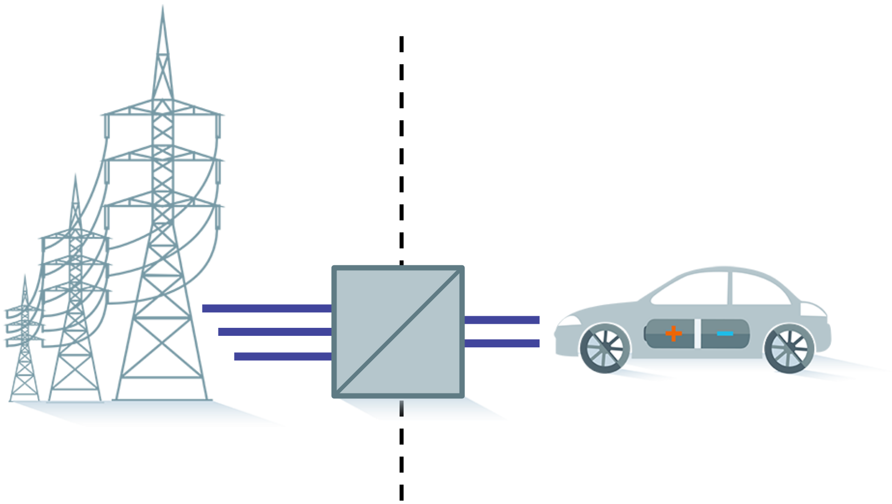
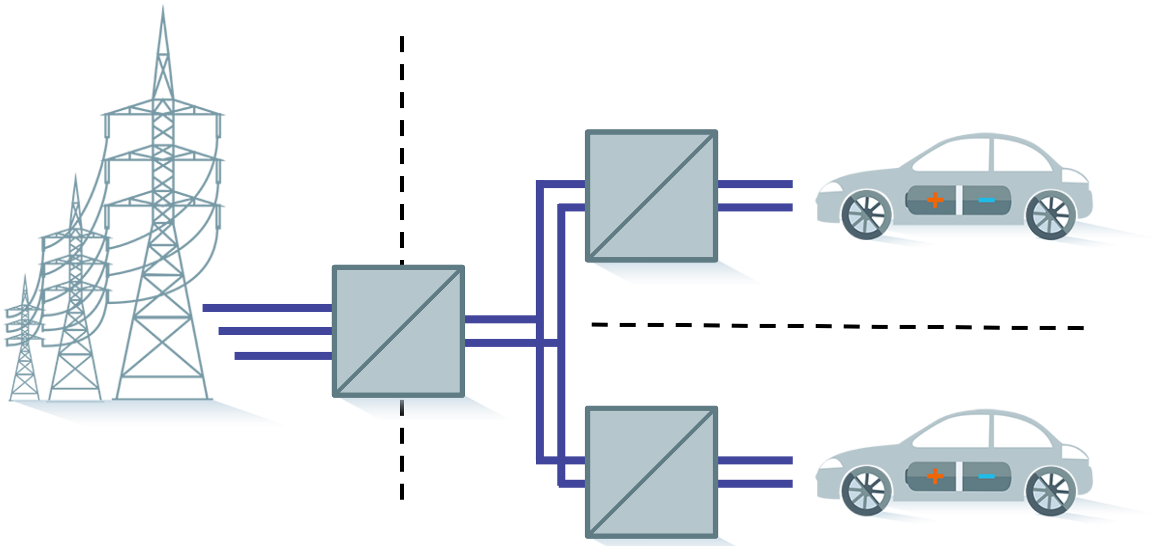
**Isolation requirements** according to IEC 61851-23

Between **AC grid** and EV to create **IT system**



Between **two EVs** in chargers with multiple outlets



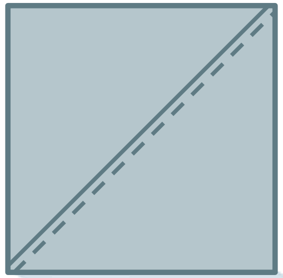
Focus of this paper

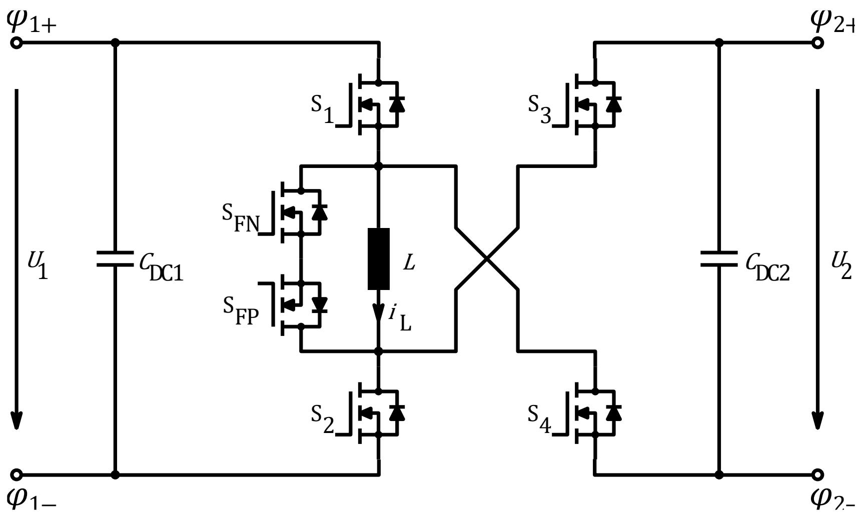
# INTRODUCTION

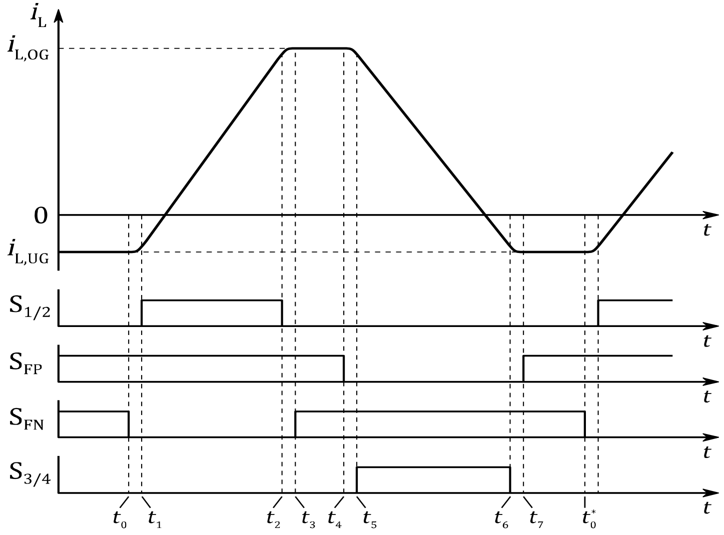


Isolated DC/DC-converters result in an immense cost and size factor due to the transformer, yet standard non-isolated topologies do not have the required fault behavior

- Introduction of converter with **Semiconductor-Based Isolation (SCI)** for charging applications in DC microgrids





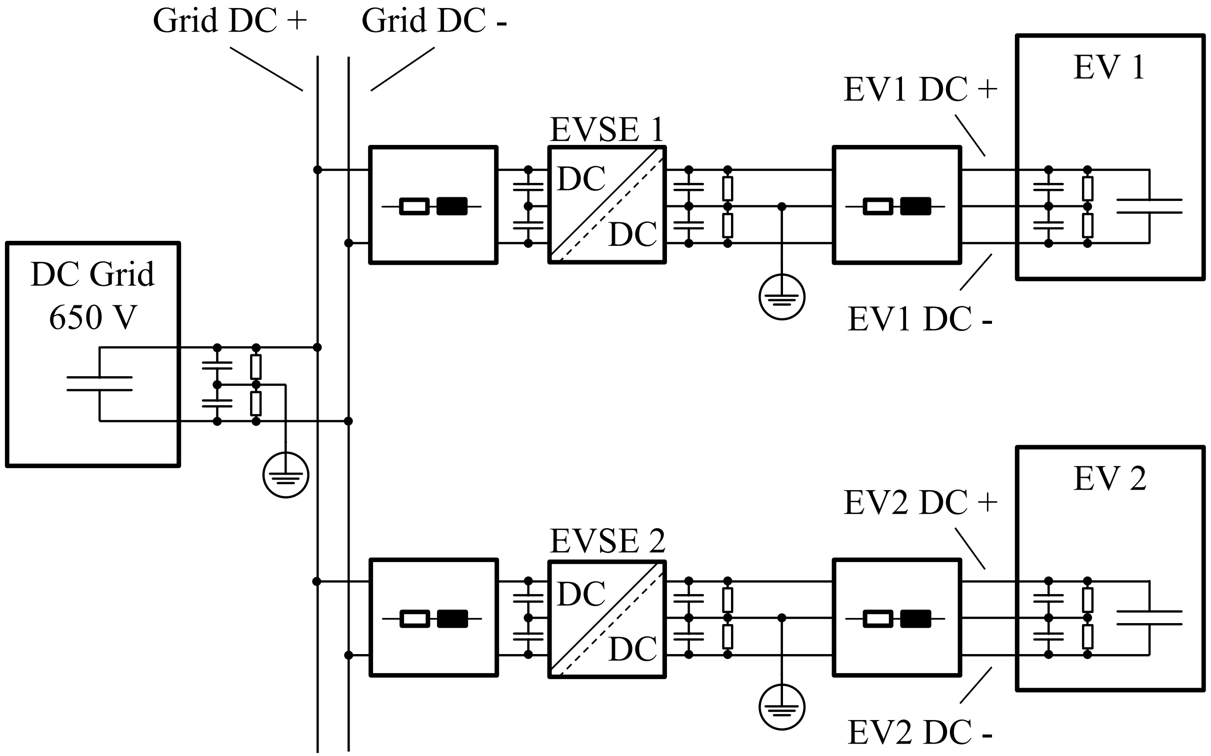



# System Description and Simulation Model

## **Simulation based** evaluation of **system behavior** during faults

- EVSE with three different converter topologies
- Common 650 V DC grid
- Grid and EVs: IT-System (High-ohmic midpoint grounding)
- Cabling modelled as RL circuits

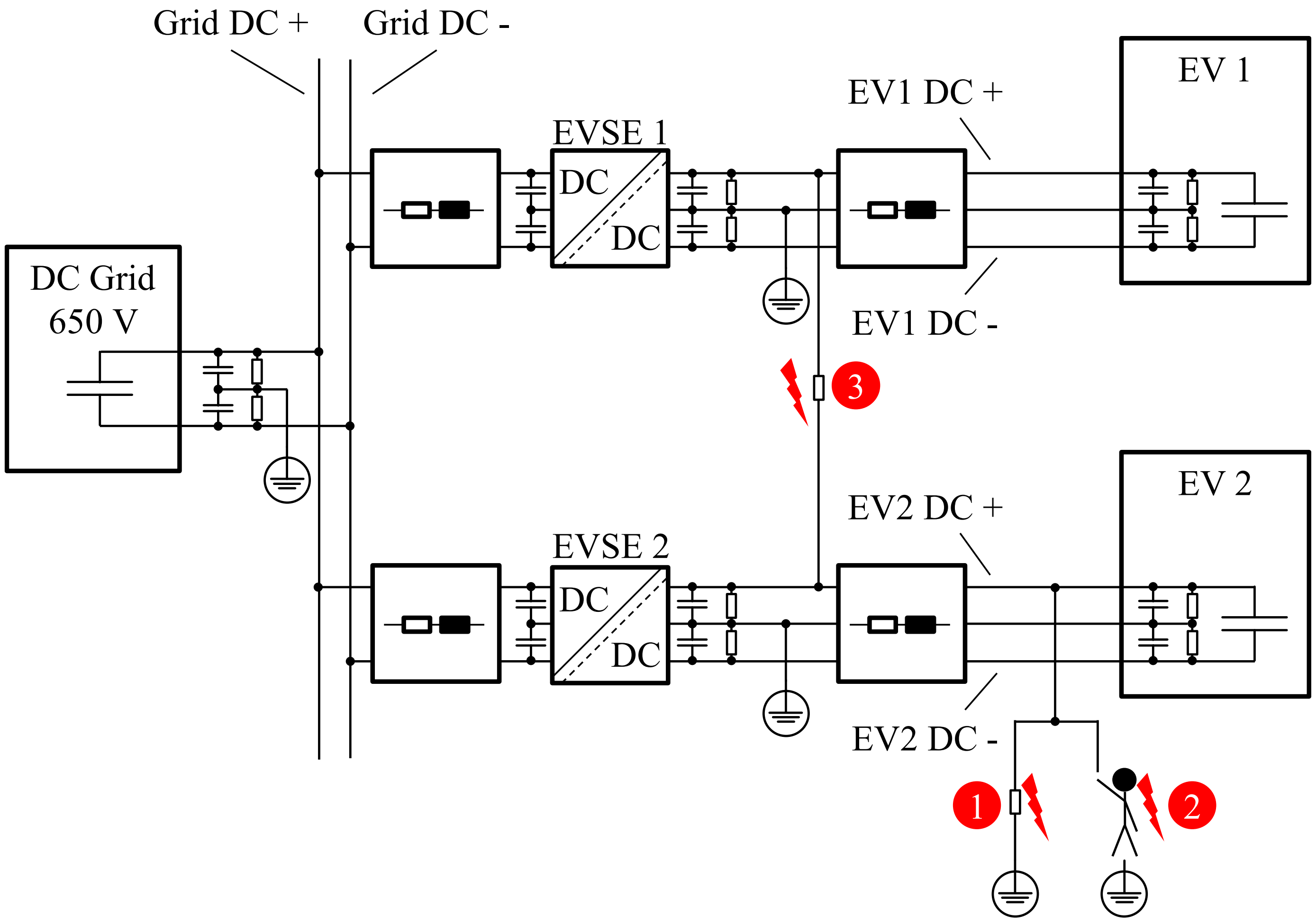
| Simulation Parameter | | Value |
|---|---|---|
| Grounding resistance | $R_{PE}$ | 1,0 MΩ |
| Y-Capacitance Grid | $C_{Y,Grid}$ | 0,5 µF |
| Y-Capacitance EVSE (each) | $C_{Y,EVSE}$ | 0,5 µF |
| Y-Capacitance EV (each) | $C_{Y,EV}$ | 2,0 µF |
| Battery voltage of EV | $U_{Bat,EV}$ | 400 V or 800 V |
| EV Battery ESR | $R_{Bat}$ | 100 mΩ |
| Line parameters grid side | $R_{Line,Grid}$ | 10 mΩ |
| | $L_{Line,Grid}$ | 4,0 µH |
| Line parameters charging cable | $R_{Line,EV}$ | 5,0 mΩ |
| | $L_{Line,EV}$ | 2,0 µH |



# System Description and Simulation Model

System behavior for three different **fault scenarios** is evaluated

1. **Ground fault** with low fault resistance
2. Classification of **touch current**
3. **Parallel fault** between vehicles with different battery voltage

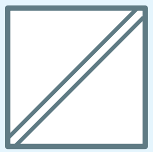
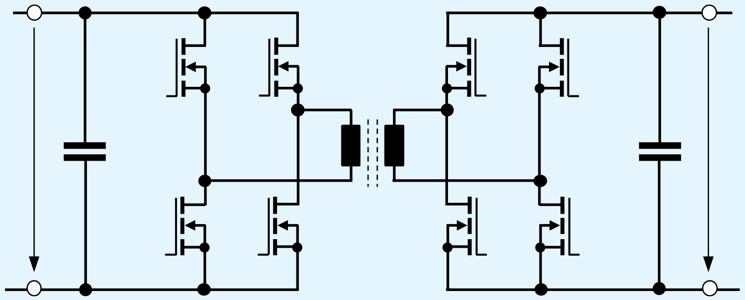
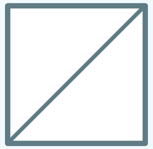
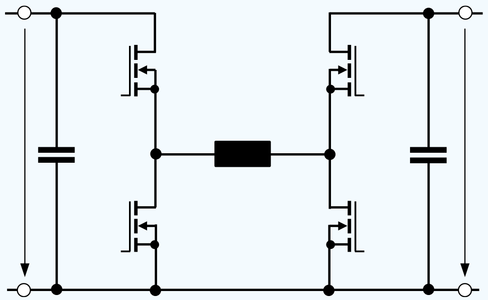
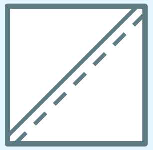
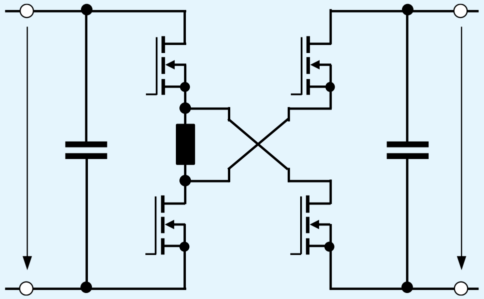


# Converter Topologies

Converter **system behavior during faults** in comparison with standard **converter topologies**

Simulation of all faults once with each type

- **DAB** as isolated reference scenario following requirements of IEC 61851-23
- **H-Bridge** to showcase system behavior or standard non-isolated converters
- **SCI converter** to be evaluated

| Topology | Function | Basic Schematic |
|---|---|---|
| DAB  | Isolated reference following standard |  |
| H-Bridge  | Non-isolated reference |  |
| SCI  | New topology to be evaluated |  |

# Simulation of Fault Scenarios

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Fault from EV2 DC+ to PE

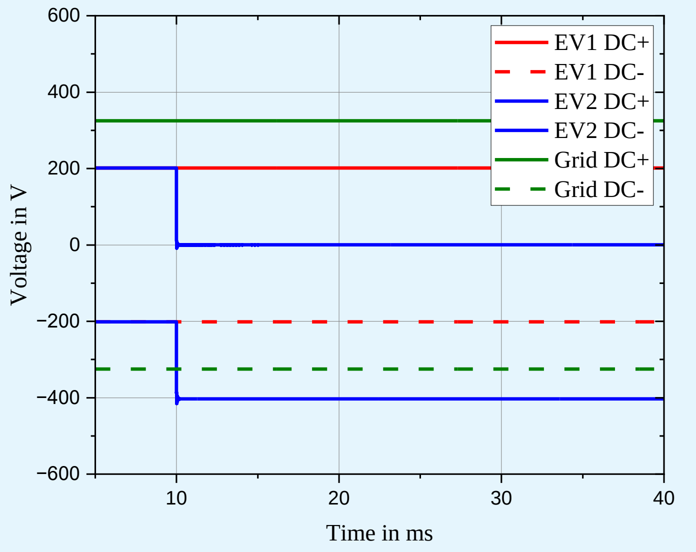
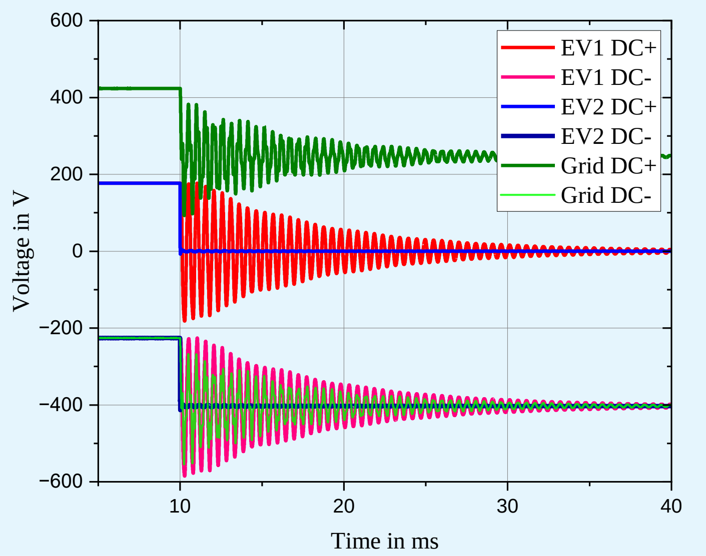
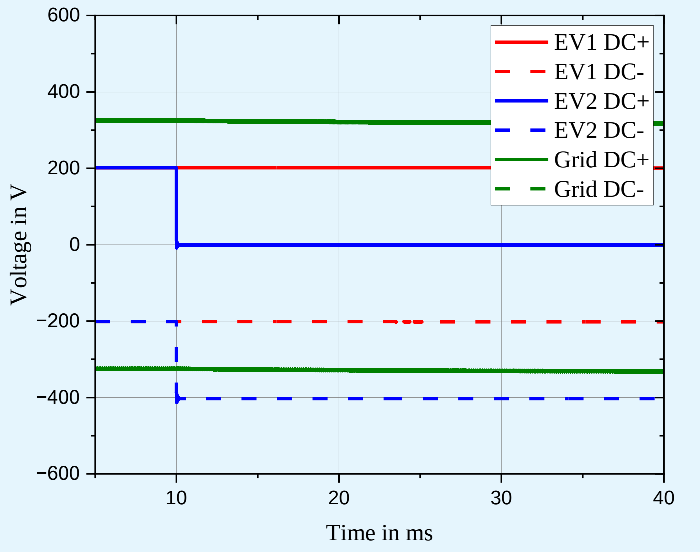
EV1: 400 V

EV2: 400 V

$R_{fault}$: 100 mΩ

## Potential in reference to PE during ground faults

- **DAB**: No influnce of fault on grid or other EV → ✓
- **H-Bridge:** Fault in EV2 results in isolation fault in EV1 and grid → ✗
- **SCI**: slight slope of grid side voltage potential eventually settling at ±315 V due to MOSFET output capacitances → ✓

| | DAB | H-Bridge | SCI |
|---|---|---|---|
| **Grid and EV voltage potentials in reference to PE** |  |  |  |

# Simulation of Fault Scenarios

## Touch current evaluation according to IEC 60479-1/2

- **c1-Line** as absolut upper limit
- **DAB/SCI:** touch current limited to faulty vehicle → ✓
- **H-Bridge:** touch current influenced by all EVs and grid → heavily depending on grid size and configuration → ?

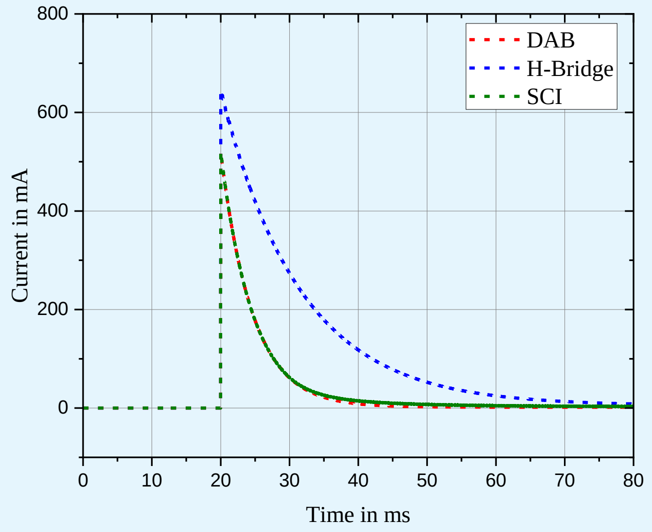
Fault from EV2 DC+ to person

EV1: 400 V

EV2: 800 V

$R_{Body}$: 775 Ω

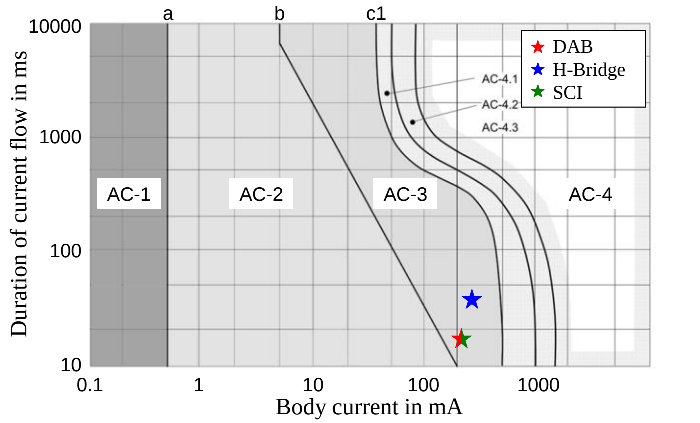
**Touch current**




**Values**

| Converter | Parameter | Value |
|---|---|---|
| DAB | $I_{C,peak}$ | 520 mA |
| | $I_{C,rms}$ | 212 mA |
| | 3τ | 14 ms |
| H-Bridge | $I_{C,peak}$ | 640 mA |
| | $I_{C,rms}$ | 260 mA |
| | 3τ | 36,5 ms |
| SCI | $I_{C,peak}$ | 520 mA |
| | $I_{C,rms}$ | 212 mA |
| | 3τ | 15 ms |

**Classification**



# Simulation of Fault Scenarios

## Parallel fault of two EVs

- **H-Bridge**: High damage potential due to direct connection of 400 V and 800 V battery system → ✗
- **DAB/SCI**: Short bursts due to capacitive voltage balancing currents otherwise uninterrupted charging operation → ✓

Fault from EVSE1 DC+ to EVSE2 DC+

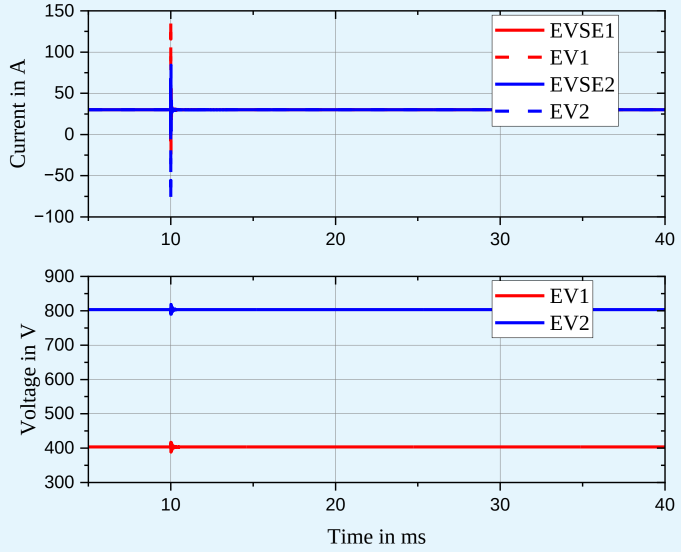
EV1: 400 V

EV2: 800 V

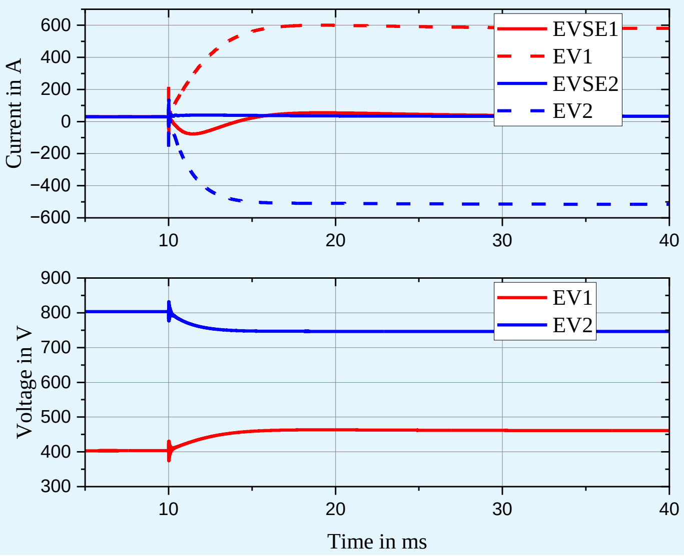
$R_{fault}$: 500 mΩ

**EV input current EVSE output current and EV voltage**

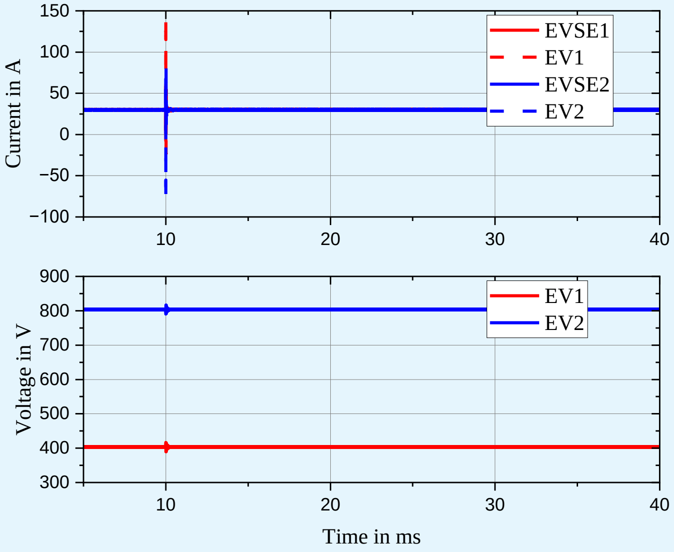
**DAB**




**H-Bridge**




**SCI**



# CONCLUSION



The **semiconductor-based isolating converter** topology shows a system behavior during faults **similar to isolated converters** while offering immense potential of **cost and size benefits**.

Designing of a charging park, especially when integrating it into a (industrial) DC microgrid, can be realized at the **same level of safety** and **without additional protection devices**.