Power in electrical safety

Electrical safety for hybrid and electric vehicles
Overview

1. General
2. Drive concepts
3. Standards
4. Bender solutions
The reliable and safe supply of power

Electrical safety in vehicles and mobile units

Vehicles

Mobile units

Land

Water

Water

Land

Air

Road

Rail

next pages

Rail applications
DIN EN 50155
(VDE 0115-200)
rolling stock

Railway signalling systems
DIN VDE 0831
(VDE 0831)

Electrical installations on ships
IEC 92-202
DNV, GL …, LR …,

DIN VDE 0129-507
yachts

Mobile and fixed offshore units
IEC 61892-…
DNV, GL …, LR …,

DIN VDE 0100-721
yachts, boats, caravans, moorings

Elec. systems in vehicles or transportable units

Mobile generators
DIN VDE 0100-717
IEC 60364-7-717

DIN VDE 0100-551
IEC 60364-5-51

DNV, GL …, LR …,
Electrical vehicles with varying drive concepts, requirements and applications

- **Electric motor drive**
  - Electrical grid / solar
  - Charger
  - Energy storage
  - Vehicle elec. sys.
  - Elec. motor

- **Comb. engine / elec. motor drive (hybrid)**
  - Fuel
  - Comb. engine
  - Generator
  - 3 AC
  - Battery
  - Inverter
  - Elec. motor
  - Elec. equip.

- **Comb. engine drive / elec. loads**
  - Fuel
  - Generator
  - Elec. grid
  - Comb. engine
  - Generator
  - Transformer
  - Vehicle elec. system
  - Electrical loads
Hybrid principle

**THS Operation**

1. Starting out or moving under very low load

   - Generator (A)
   - Inverter
   - Electric motor
   - Planetary gear
   - Transmission
   - Gasoline engine idling or stopped

   **Motive power path**

   **Electrical power path**

2. Normal driving

   - Generator (C)
   - Inverter
   - Electric motor
   - Planetary gear
   - Transmission

3. Full-throttle acceleration

   - Generator (A)
   - Inverter
   - Electric motor
   - Planetary gear
   - Transmission

4. Deceleration or braking

   - Generator (A)
   - Gasoline engine idling or stopped
   - Inverter
   - Electric motor
   - Planetary gear
   - Transmission
Hybrid unit Toyota Prius

- Generator
- Power Split Device
- Electric motor
- 2-stage motor speed reduction device
- TORSEN® Limited Slip Differential
## Hybrid variants

<table>
<thead>
<tr>
<th>Architectural approaches</th>
<th>Micro hybrid</th>
<th>Mild hybrid</th>
<th>Medium hybrid</th>
<th>Full hybrid</th>
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<tbody>
<tr>
<td><strong>Functionality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boosting</td>
<td>passive</td>
<td>active</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Recuperation</td>
<td>limited / overload</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Electric driving</td>
<td>no</td>
<td>no</td>
<td>limited</td>
<td>yes</td>
</tr>
<tr>
<td>Start / stop</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td><strong>Vehicle elec. sys.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage level(s)</td>
<td>12 V</td>
<td>12 - 50 V</td>
<td>12 - 100...400 V</td>
<td>12 - 200...500 V</td>
</tr>
<tr>
<td><strong>Elec. machines</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power rating</td>
<td>≤ 5 kW</td>
<td>≤ 10 kW</td>
<td>≤ 15 kW</td>
<td>≥ 15 kW</td>
</tr>
</tbody>
</table>
1. General

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4. Bender solutions
Electric vehicle with traction battery

Propulsion motor

Gearbox

Charger

Battery

12 V Vehicle elec. sys.

Air cond. compressor (high voltage)

High voltage – link circuit
Electrical system (example for electric forklift truck)

Battery
24/48 80 V

A-ISOMETER®

Vehicle chassis

Ground

Hydraulics for truck functions

Propulsion drive

R_{F-DC}  

R_{F-AC}

C_e = C_e

M 3~

R_T

M 3~

M 3~
Hybrid vehicle

- Tank
- Clutch
- Gearbox
- Tank
- Gearbox
- Clutch

High voltage – link circuit

- AC/DC
- DC/DC
- DC/DC
- DC/AC
- DC/AC

Electrical energy store

14 V vehicle elec. sys.

High power loads (e.g. air cond.)

Loads connected externally

- Tank
- Gearbox
- Clutch

- Tank
- Gearbox
- Clutch

- Tank
- Gearbox
- Clutch

- Tank
- Gearbox
- Clutch
Electrical system (serial diesel-electric vehicle)
Vehicle with fuel cells
### Faults and protective measures

<table>
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<tr>
<th>Fault</th>
<th>Reason</th>
<th>Effect</th>
<th>Passive protective measures</th>
<th>Active protective measures</th>
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</thead>
<tbody>
<tr>
<td><strong>Insulation fault</strong></td>
<td>Thermal or mechanical damage to the insulation, accident</td>
<td>Electric shock, battery discharge</td>
<td>Double insulation, <strong>insulation monitoring</strong></td>
<td>Disconnection of power sources</td>
</tr>
<tr>
<td><strong>Short-circuit</strong></td>
<td>Mechanical fault, accident</td>
<td>Failure of control units</td>
<td>Emergency stopping, compliance with EMC regulations, watchdog for monitoring control unit</td>
<td>Disconnection of power sources</td>
</tr>
<tr>
<td><strong>Direct contact with high voltage</strong></td>
<td>Mechanical fault, maintenance, repair, incorrect operation</td>
<td>Electric shock</td>
<td></td>
<td>Discharge capacitors, disconnection of power sources</td>
</tr>
<tr>
<td><strong>Contact with high voltage</strong></td>
<td>Mechanical fault</td>
<td></td>
<td><strong>Insulation monitoring</strong></td>
<td>Alarm, disconnection of power sources</td>
</tr>
<tr>
<td><strong>Overvoltage</strong></td>
<td>Electrostatic charging, transients during switching, electromagnetic effect</td>
<td>Damage to components</td>
<td>Overvoltage protection</td>
<td>Connection of the vehicle to earth during refuelling and battery charging</td>
</tr>
</tbody>
</table>
Overview

1. General
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High voltage safety in vehicles

USA / CANADA
- FMVSS 305
- CMVSS 305

EUROPE
- ECE R 100

JAPAN
- Attachment 101
- Attachment 110
- Attachment 111

International standards
- ISO 6469 part 1...3
- ISO 23273
## Overview of standards

<table>
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<tr>
<th>Germany</th>
<th>International</th>
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<tr>
<td><strong>DIN VDE 0122:1986-08</strong> Elektrische Ausrüstung von Straßenfahrzeugen</td>
<td><strong>IEC 61851-1:2001-01</strong> Electric vehicle conductive charging system – Part 1: General requirements</td>
</tr>
<tr>
<td>(Electric equipment of electrical road vehicles)</td>
<td></td>
</tr>
<tr>
<td><strong>DIN EN 61851-1 (VDE 0122 T1):2001-11</strong> Konduktive Ladesysteme für</td>
<td><strong>IEC 61851-21:2001-05</strong> Electric vehicle conductive charging system – Part 21: EV requirements for conductive connection to an ac/dc supply</td>
</tr>
<tr>
<td>Elektrofahrzeuge - Teil 1: Allgemeine Anforderungen</td>
<td></td>
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<tr>
<td><strong>DIN EN 61851-21 (VDE 0122 T 2-1):2002-10</strong> Konduktive Ladesysteme für</td>
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<tr>
<td>Elektrofahrzeuge – AC/DC-Versorgung</td>
<td></td>
</tr>
<tr>
<td><strong>DIN EN 61851-22 (VDE 0122 Teil 2-2):2002-10</strong> – Konduktive</td>
<td></td>
</tr>
<tr>
<td>Ladesysteme für Elektrofahrzeuge – AC-Ladestation</td>
<td></td>
</tr>
<tr>
<td>Besondere Festlegungen für die Sicherheit Teil 3: Schutz der Benutzer gegen elektrische Gefahren</td>
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### Overview of standards

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|         | **SAE J1766:2005-04**  
Recommended Practice for Electric and  
Hybrid Electric Vehicle Battery Systems Crash Integrity Testing |
|         | **SAE J2578:2009-1**  
Recommended Practice for General Fuel Cell Vehicle Safety |
|         | **SAE J 2344**  
Guideline for Electrical Vehicle Safety |
|         | **SAE J 1772**  
Electric vehicle Conductive Charger |
|         | **ISO 23273-3:2006-11**  
Fuel cell road vehicles – Safety specifications –  
Part 3: Protection of persons against electric shock |
|         | **ISO 6493-3**  
Electric road vehicles – Safety specifications –  
Part 3: Protection of persons against electric hazards |
|         | **TP-305-00:2005-12**  
U.S. Department of Transportation FMVSS305: Electric powered vehicles:  
Electrolyte Spillage and Electrical shock protection |
|         | **Regulation No. 100**  
Agreement concerning the adoption of uniform conditions  
technical prescriptions for wheeled vehicles |
Overview

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Example of possible insulation faults in electric/hybrid vehicles