Surge Protection Standards and Design for Electronic Equipment in Railway Systems - Systems Training

Toni Ray
Systems Engineering & Marketing – Industrial Systems –Industrial Transport
Detailed agenda

- Types of trains
- Powering a train
- Overview of railway standards for electrical systems
- Test setup for DC/DC converters
- Input protection circuit block diagrams
Main types of trains

- Trains types are typically grouped by speed and configuration

- Freight
- High-speed
- EMU
- Metro/Tram
Main types of trains

• Centralized Power
  – Dedicated cars used for power
    • Freight Trains
    • Some High Speed Trains

• Distributed Power
  – Traction units distributed over multiple cars
    • Intercity/Metro < 65 km/h
    • Express/Regional < 150 km/h
    • High Speed > 200 km/h
    • Classified by power source
      – EMU Electric Multiple Unit
      – DMU Diesel Multiple Unit
      – Bi-mode (Electric + Diesel)
Powering a train

- Engine
- Generator
- Overhead / Third Rail
- Battery
- AC/DC
- DC/AC
- Aux Power System
- Traction Motor Supply
- Auxiliary Supply
Segmentation by Train Type (Speed vs Power)

- **High speed EMU**
  - Speed: 300k/h
  - Power: >10MW

- **Express/Regional EMU**
  - Speed: 150k/h
  - Power: 1MW

- **Tram/Metro**
  - Speed: 50k/h
  - Power: 100kW

- **Freight**
  - Speed: 50k/h
  - Power: 100kW
Surge Sources

• Changing supply section
  – Train enters an energized line from a neutral zone
• Pantograph loss of contact
  – Arcing at the 25kV line after a loss of contact
• Change from coasting to traction mode
  – High switching surges generated at startup
• Lightning
• Opening/Closing main switch
• Operations on the electrical grid
Adverse effects on electrical equipment

• Lights and monitors flicker
• Accuracy of detection devices effected
• Possible data loss
• Reduced load life
Railway Electrification System Standards

• Most popular standards
  – French NF F standards : NF-F 48 series, NF-F-01-510, NF-F67000, ...
  – UK BRB/RIA standards : RIA12, RIA13, RIA18, RIA20, BR1900, ..
  – German standards : VDE 0435, IEC571, 19 Pfl, ..... 
  – Italian FS standards : ST306158, ST304142, ..... 
  – American standards published by the Association of American Railroads : «Signal Manual», Specification 110, ...

• European Norm EN standards are becoming more widely adopted
  – EN 50155 Railways Applications Electronic Equipment Used on Rolling Stock
  – EN 50125 Railway Applications; Environmental Conditions for rolling stock
  – EN50163 Supply voltages of traction systems
Overview of input voltage requirements EN 50155

• Variations of voltage supply
  – Nominal voltage equipment is defined as 24V, 48V, 72V, 96V, 110V
  – Permanent input voltage range
    • Electronic equipment shall operate normally for a supply voltage within the range of 0.7x to 1.25x
  – Supply change over and disruption
    • Class C1: 0.6x 100ms
    • Class C2: operate during supply break of 30ms
    • Class S2: 10ms interruption shall not cause failure
  – Voltage fluctuations
    • No deviation of function for values of supply voltage in the range of 0.6x to 1.4x for 100ms
    • No damage (not fully functional) for values of supply voltage in the range of 1.25x to 1.4x for 1s

<table>
<thead>
<tr>
<th>EN50155</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent input</td>
<td>0.7x-1.25x</td>
</tr>
<tr>
<td>Brownout 100ms</td>
<td>0.6x</td>
</tr>
<tr>
<td>Fluctuation 100ms</td>
<td>0.6x-1.4x</td>
</tr>
<tr>
<td>Overvoltage 1s</td>
<td>1.4x</td>
</tr>
</tbody>
</table>
Overview of input voltage requirements RIA 12

• Variations of voltage supply
  – Permanent input voltage range
    • Same as EN 50155
  – Supply interruption or change over
    • Same as EN 50155
  – Supply surge
    • More aggressive than EN 50155
      – 1.5x for 1s
      – 3.5x for 20ms

<table>
<thead>
<tr>
<th></th>
<th>EN50155</th>
<th>RIA 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permanent input</td>
<td>0.7x-1.25x</td>
<td>0.7x-1.25x</td>
</tr>
<tr>
<td>Brownout 100ms</td>
<td>0.6x</td>
<td>0.6x</td>
</tr>
<tr>
<td>Overvoltage 100ms</td>
<td>0.6x-1.4x</td>
<td></td>
</tr>
<tr>
<td>Overvoltage 1s</td>
<td>1.4x</td>
<td>1.5x</td>
</tr>
<tr>
<td>Overvoltage 20ms</td>
<td></td>
<td>3.5x</td>
</tr>
</tbody>
</table>
## Overview of conducted immunity requirements

### EN50155 / EN50121-3-2

<table>
<thead>
<tr>
<th>Level (V)</th>
<th>Duration $T_r/T$</th>
<th>Reference Standard</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1.5/50 μs 42Ω 0.5μF</td>
<td>IEC 61000-4-5 Line to Line</td>
<td>B</td>
</tr>
<tr>
<td>2000</td>
<td>1.5/50 μs 42Ω 0.5μF</td>
<td>IEC 61000-4-5 Line to Ground</td>
<td>B</td>
</tr>
<tr>
<td>2000</td>
<td>5/50 ns 5kHz</td>
<td>IEC 61000-4-4</td>
<td>A</td>
</tr>
<tr>
<td>6000</td>
<td>IEC 61000-4-2 Contact</td>
<td>A</td>
<td></td>
</tr>
<tr>
<td>8000</td>
<td>IEC 61000-4-2 Air</td>
<td>A</td>
<td></td>
</tr>
</tbody>
</table>
### Overview of RIA 12 transient requirements

<table>
<thead>
<tr>
<th>Direct Transient Trapezoidal</th>
<th>Direct Transient Capacitor Discharge Voltage</th>
<th>Indirect Transient Trapezoidal</th>
<th>Indirect Transient Capacitor Discharge Voltage</th>
<th>Duration</th>
<th>Source Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 V</td>
<td>960 V</td>
<td>100 µs</td>
<td>100 µs</td>
<td>5 Ω</td>
<td></td>
</tr>
<tr>
<td>1500 V</td>
<td>1800 V</td>
<td>50 µs</td>
<td>50 µs</td>
<td>5/5/100/100 Ω</td>
<td></td>
</tr>
<tr>
<td>3000 V</td>
<td>3600 V</td>
<td>5 µs</td>
<td>5 µs</td>
<td>100 Ω</td>
<td></td>
</tr>
<tr>
<td>4000 V</td>
<td>4800 V</td>
<td>1 µs</td>
<td>1 µs</td>
<td>100 Ω</td>
<td></td>
</tr>
<tr>
<td>7000 V</td>
<td>8400 V</td>
<td>0.1 µs</td>
<td>0.1 µs</td>
<td>100 Ω</td>
<td></td>
</tr>
</tbody>
</table>
RIA 12 trapezoidal test parameters

- **Test Circuit**
  - Voltage Level (U)
  - Series Resistor ($R_s$)

- **Waveform**
  - Minimum Duration (D)
  - Maximum Duration (d)
  - Voltage Level (U)

### RIA 12

<table>
<thead>
<tr>
<th>Voltage (U)</th>
<th>Indirect Transient Trapezoidal</th>
<th>Duration (d/D)</th>
<th>Source Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 V</td>
<td>10/100 µs</td>
<td>5 Ω</td>
<td></td>
</tr>
<tr>
<td>1500 V</td>
<td>1500 V</td>
<td>5/100 Ω</td>
<td></td>
</tr>
<tr>
<td>3000 V</td>
<td>3000 V</td>
<td>0.5/50 µs</td>
<td>100 Ω</td>
</tr>
<tr>
<td>4000 V</td>
<td>4000 V</td>
<td>0.1/1 µs</td>
<td>100 Ω</td>
</tr>
<tr>
<td>7000 V</td>
<td>7000 V</td>
<td>0.05/0.1 µs</td>
<td>100 Ω</td>
</tr>
</tbody>
</table>
RIA 12 alternative test for supply surge

- **Test Circuit**
  - Voltage Level (U)
  - Series Resistor ($R_s$)

- **Waveform**
  - Minimum Duration (D)
  - Voltage Level (U)
  - Supply Voltage (V)

### RIA 12

<table>
<thead>
<tr>
<th>Voltage Level</th>
<th>Duration (D)</th>
<th>Source Impedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5x</td>
<td>20 ms</td>
<td>0.2 Ω</td>
</tr>
<tr>
<td>1.5x</td>
<td>1 s</td>
<td>0.2 Ω</td>
</tr>
</tbody>
</table>

3 Phase 50/60Hz AC Supply

3 Phase Half Controlled Thyristor Bridge

Gate Firing Control

To Equipment Under Test

Control System Supply Voltage

3.5x 20 ms 0.2 Ω

1.5x 1 s 0.2 Ω
RIA 12 capacitor discharge test parameters

- **Test Circuit**
  - Voltage Level (U)
  - Series Resistor (R_s)

- **Waveform**
  - Minimum Duration (D)
  - Maximum Duration (d)
  - Voltage Level (U)

### RIA 12

<table>
<thead>
<tr>
<th>Direct Transient</th>
<th>Indirect Transient</th>
<th>Duration (d/D)</th>
<th>Source Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>960 V</td>
<td>1800 V</td>
<td>10/100 µs</td>
<td>5 Ω</td>
</tr>
<tr>
<td>1800 V</td>
<td>1800 V</td>
<td>5/50 µs</td>
<td>5/100 Ω</td>
</tr>
<tr>
<td>3600 V</td>
<td>3600 V</td>
<td>0.5/5 µs</td>
<td>100 Ω</td>
</tr>
<tr>
<td>4800 V</td>
<td>4800 V</td>
<td>0.1/1 µs</td>
<td>100 Ω</td>
</tr>
<tr>
<td>8400 V</td>
<td>8400 V</td>
<td>0.05/0.1 µs</td>
<td>100 Ω</td>
</tr>
</tbody>
</table>

![Test Circuit Diagram](image_url)
Common protection devices

• Transient voltage suppressors (TVS)
  – Acts as a clamping circuit to redirect any high energy pulses to ground

• Metal oxide varistors (MOV)
  – Voltage dependent resistor shunts the current created by excessive voltage

• Thyristor
  – Acts as a switch to control flow of current

• Gas discharge tube (GDT)
  – Dissipate voltage through contained plasma gas
Input voltage protection circuit block diagram

- TVS and MOV devices at the input provide protection from the input high voltage spikes.
- Filter module provides protection to meet EMC requirements.
- Transient protection circuit is optional and only needed to meet the additional requirements of the RIA 12 standard.
- Hold-up circuit provides energy to meet input voltage drop-out requirements.
Surge Protection Standards for Railway

- EN 50155 – Railway applications – Electronic equipment used on rolling stock
  - References EN 50121-3-2 Railway Applications – Electromagnetic compatibility Part 3-2: Rolling stock - Apparatus
  - References IEC 61000-4-4 Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test

- RIA 12 - General Specification for Protection of Traction and Rolling Stock Electronic Equipment from transients and Surges in DC Control Systems
  - References IEC 571 Rules for Electronic Equipment used on Rail Vehicles
  - RIA 13 General Specification for Electronic Equipment used on Traction and Rolling Stock