

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

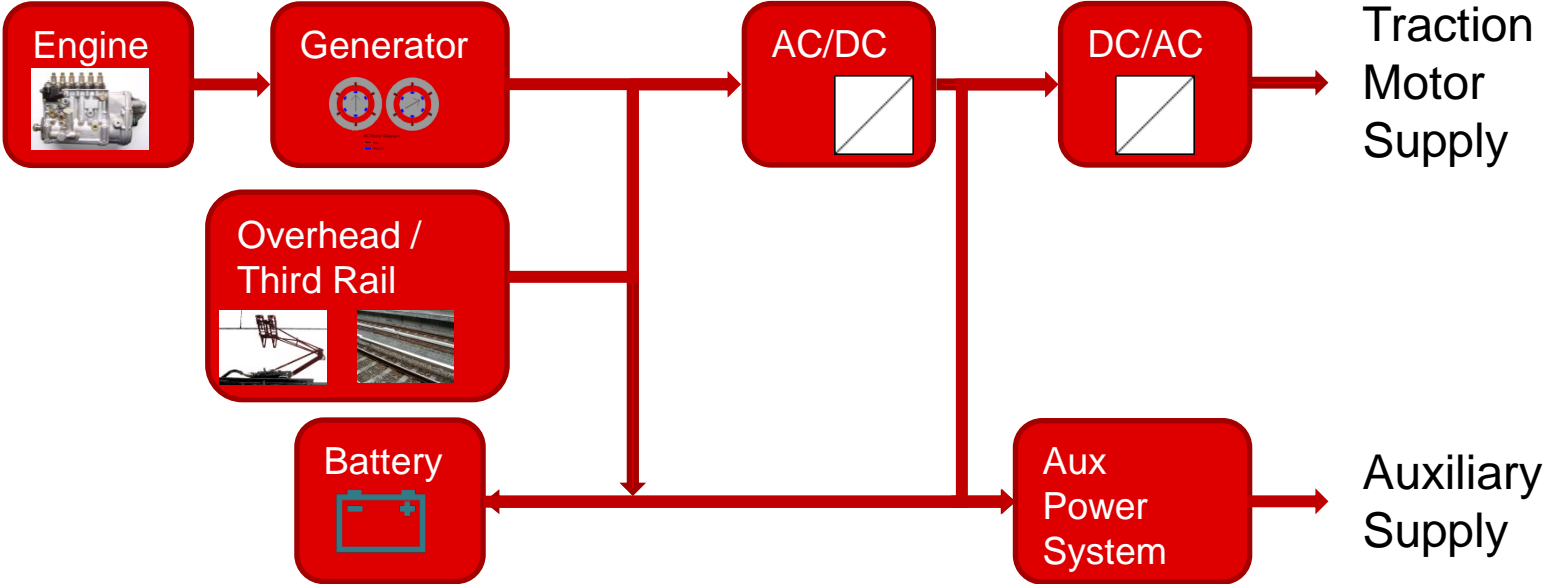


- Distributed Power

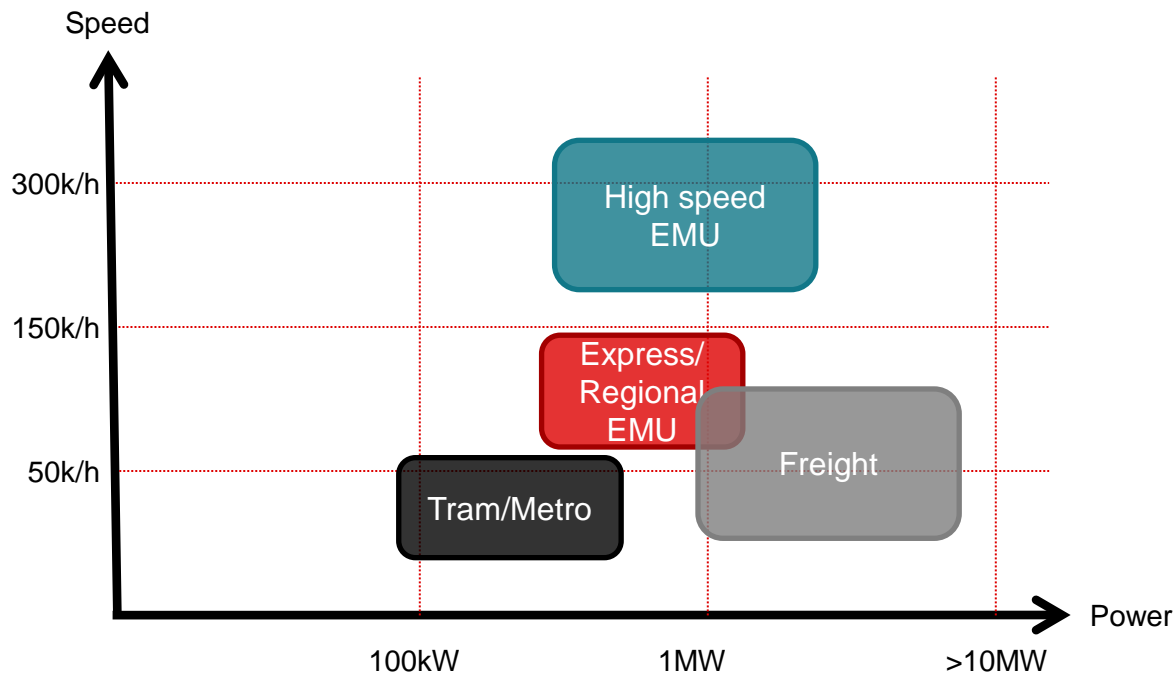
- Traction units distributed over multiple cars
 - Intercity/Metro < 65 km/h
 - Express/Regional < 150 km/h
 - High Speed > 200 km/h
 - Classified by power source
 - EMU Electric Multiple Unit
 - DMU Diesel Multiple Unit
 - Bi-mode (Electric + Diesel)



Powering a train



Segmentation by Train Type (Speed vs Power)



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

EN50155	
	Range
Permanent input	0.7x-1.25x
Brownout 100ms	0.6x
Fluctuation 100ms	0.6x-1.4x
Overvoltage 1s	1.4x

Overview of input voltage requirements RIA 12

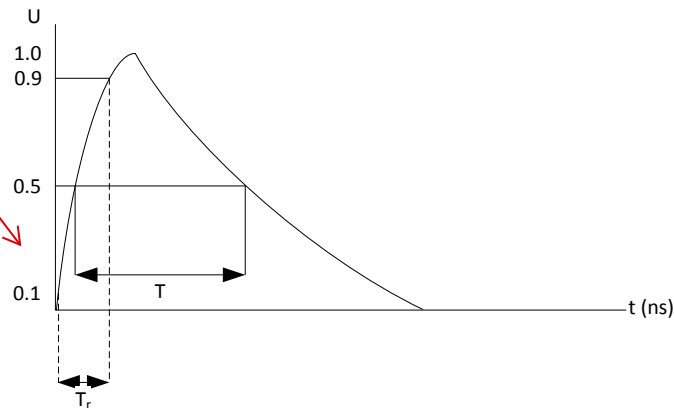
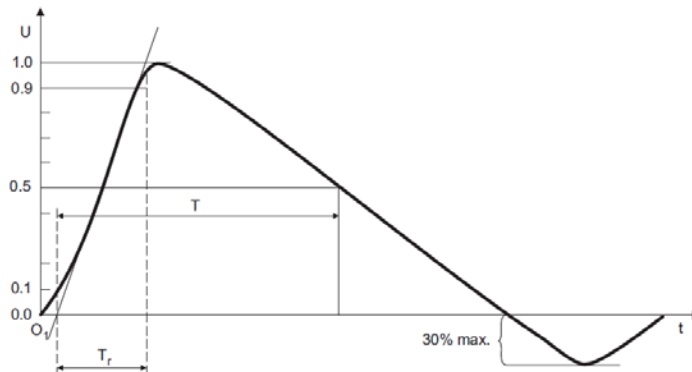
- Variations of voltage supply
 - Permanent input voltage range
 - Same as EN 50155
 - Supply interruption or change over
 - Same as EN 50155
 - Supply surge
 - More aggressive than EN 50155
 - 1.5x for 1s
 - 3.5x for 20ms

	EN50155	RIA 12
	Range	Range
Permanent input	0.7x-1.25x	0.7x-1.25x
Brownout 100ms	0.6x	0.6x
Overshoot 100ms	0.6x-1.4x	
Overshoot 1s	1.4x	1.5x
Overshoot 20ms		3.5x

Overview of conducted immunity requirements

EN50155 / EN50121-3-2

Level (V)	Duration T_r/T	Reference Standard	Criteria
1000	1.5/50 μs 42 Ω 0.5 μF	IEC 61000-4-5 Line to Line	B
2000	1.5/50 μs 42 Ω 0.5 μF	IEC 61000-4-5 Line to Ground	B
2000	5/50 ns 5kHz	IEC 61000-4-4	A
6000		IEC 61000-4-2 Contact	A
8000		IEC 61000-4-2 Air	A



Overview of RIA 12 transient requirements

RIA 12					
Direct Transient Trapezoidal	Direct Transient Capacitor Discharge Voltage	Indirect Transient Trapezoidal	Indirect Transient Capacitor Discharge Voltage	Duration	Source Z
800 V	960 V			100 μ s	5 Ω
1500 V	1800 V	1500 V	1800 V	50 μ s	5/5/100/100 Ω
3000 V	3600 V	3000 V	3600 V	5 μ s	100 Ω
4000 V	4800 V	4000 V	4800 V	1 μ s	100 Ω
7000 V	8400 V	7000 V	8400 V	0.1 μ s	100 Ω

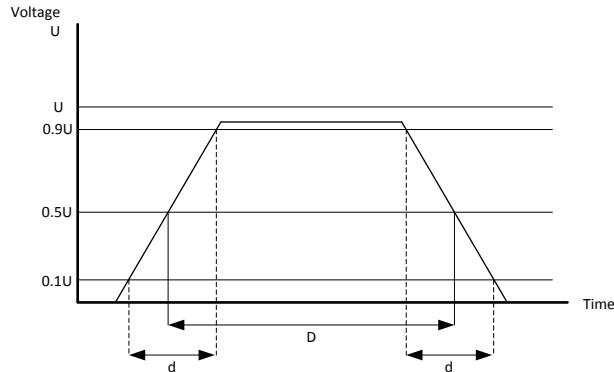
RIA 12 trapezoidal test parameters

- Test Circuit

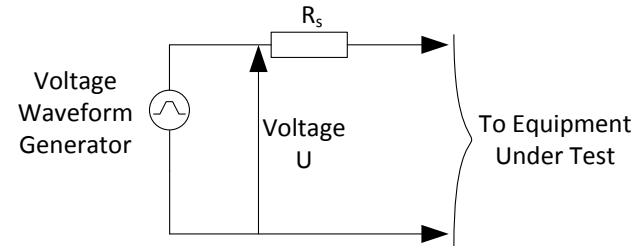
- Voltage Level (U)
- Series Resistor (R_s)

- Waveform

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

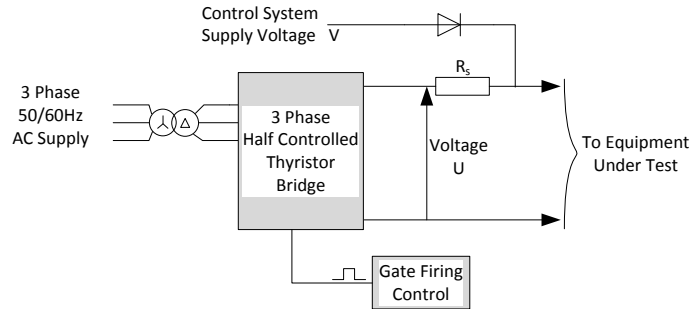


RIA 12			
Direct Transient Trapezoidal	Indirect Transient Trapezoidal	Duration (d/D)	Source Z
800 V		10/100 μ s	5 Ω
1500 V	1500 V	5/50 μ s	5/100 Ω
3000 V	3000 V	0.5/5 μ s	100 Ω
4000 V	4000 V	0.1/1 μ s	100 Ω
7000 V	7000 V	0.05/0.1 μ s	100 Ω

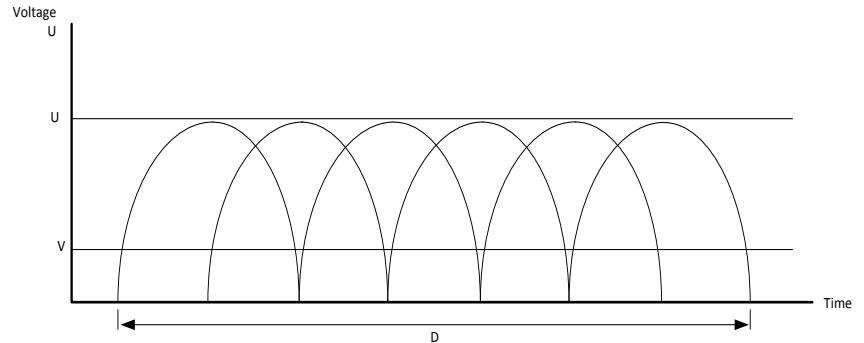


RIA 12 alternative test for supply surge

- Test Circuit
 - Voltage Level (U)
 - Series Resistor (R_s)
- Waveform
 - Minimum Duration (D)
 - Voltage Level (U)
 - Supply Voltage (V)



RIA 12		
Voltage Level	Duration (D)	Source Impedance
3.5x	20 ms	0.2 Ω
1.5x	1 s	0.2 Ω



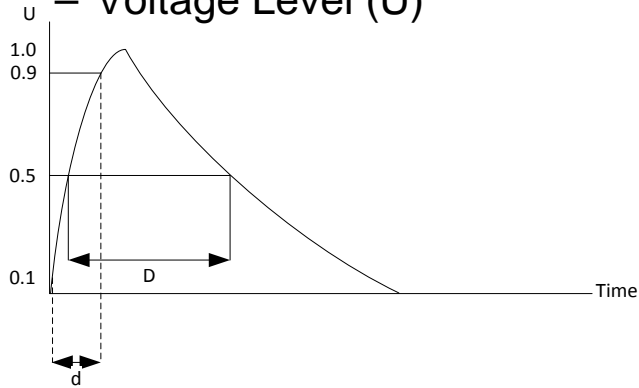
RIA 12 capacitor discharge test parameters

- Test Circuit

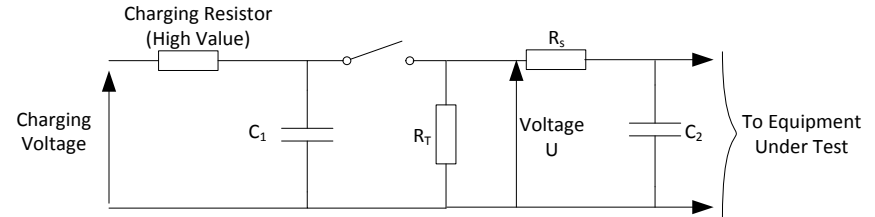
- Voltage Level (U)
- Series Resistor (R_s)

- Waveform

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



RIA 12			
Direct Transient	Indirect Transient	Duration (d/D)	Source Z
960 V		10/100 μ s	5 Ω
1800 V	1800 V	5/50 μ s	5/100 Ω
3600 V	3600 V	0.5/5 μ s	100 Ω
4800 V	4800 V	0.1/1 μ s	100 Ω
8400 V	8400 V	0.05/0.1 μ s	100 Ω

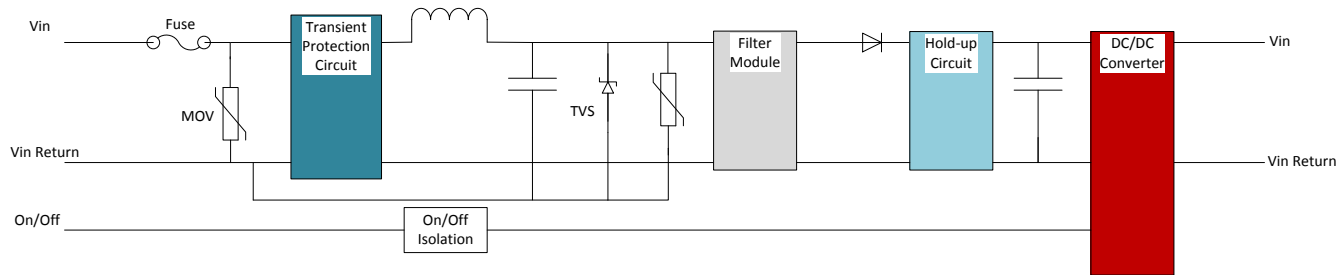


Common protection devices

- 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