Earthing in railway installations

Jernbaneverket Technical Railway Technology

Øyvind Stensby, 5 February 2016
Outline of this presentation

• Introduction to electrified railways and the various overhead contact line systems
• Legislation – Acts, regulations, TSIs and standards
• Some important regulatory requirements
• Hazard identification – what particular factors do we have to deal with on electrified railways?
  – We list 7 situations
• Review of hazards 1–7
  – 1–3 slides for each hazard
• Brief description of the interface between the railway's return circuit and the network companies' earthing systems
• New Technical Regulations
Electrified railways

22 – 132 kV
6,3 kV
4 – 5 kV
15 (16,5) kV

50 Hz trefase
16 2/3 Hz enfase
Skinner

16 2/3 Hz enfase
15 (16,5) kV

50 Hz trefase

22 – 132 kV

3~/1~
50 Hz
18 2/3 Hz

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Electrified railways – Running rails

- Return route for current from trains
- Reference potential for equalisations
- Earth electrode
- Train detection

- Rails must also have certain mechanical properties in order to withstand the forces exerted by trains.
Overhead contact line systems

Simple overhead contact line system

Draining transformer system with return in running rails
More overhead contact line systems

Draining transformer with return-current conductor

Autotransformer system with PL, NL and segmented overhead contact line system
What governs us?

Laws:
• Act relating to the inspection of electrical appliances and equipment (Electrical Inspection Act)
• Act on the establishment and operation of railways, including tramways, underground railways and suburban railways, etc. (Railways Act)

Regulations:
• Regulations relating to electrical supply installations (FEF)
• Regulations relating to low voltage electrical installations (FEL)
• Regulations relating to interoperability of the railway system (Interoperability Regulations)
• Technical specifications for interoperability (TSIs)

Standards:
• NEK 900 (EN 50122-1)
• NEK 440
• NEK 400

Company requirements:
• NNRA (Norwegian National Rail Administration): Technical Regulations
An important regulatory requirement

Section 8-6 of FEF
Systems must be designed to ensure that available differences in potential, touch voltage, earth leakage current and current in earthing conductors do not represent a risk of personal injury or damage to equipment or material.
## Hazard identification

<table>
<thead>
<tr>
<th>Identification</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard 1</td>
<td>Touch hazard</td>
<td>Insulation failure in traction power supply installation</td>
</tr>
<tr>
<td>Hazard 2</td>
<td>Touch hazard</td>
<td>Overhead contact line system may come into contact with conductive components and cause them to become energised</td>
</tr>
<tr>
<td>Hazard 3</td>
<td>Touch hazard</td>
<td>The pantograph on a train may come into contact with conductive components and cause them to become energised</td>
</tr>
<tr>
<td>Hazard 4</td>
<td>Touch hazard</td>
<td>Loads and short circuits may create a difference in potential between the return circuit and the surrounding area</td>
</tr>
<tr>
<td>Hazard 5</td>
<td>Damage to equipment</td>
<td>Return current and short-circuit current may pass through conductors that are connected in parallel with the return circuit</td>
</tr>
<tr>
<td>Hazard 6</td>
<td>Operational disruption; railway accident</td>
<td>Fault in train detection</td>
</tr>
<tr>
<td>Hazard 7</td>
<td>Damage to equipment</td>
<td>Lightning current</td>
</tr>
</tbody>
</table>
Hazard 1: Insulation failure in traction power supply

This hazard is managed by equalising all exposed conductive components to the return circuit.

All short circuits occurring as a result of the insulation failure will then go directly to the return circuit:

- touch voltage is minimised
- fault is detected by the protection equipment and results in (almost) immediate disconnection of the fault.
Hazards 2 and 3: Overhead contact line and live pantograph in contact with conductive components

EN 50122-1:

'overhead contact line zone': the risk zone into which the overhead contact line can fall

'pantograph zone': the risk zone into which a live pantograph can stray in the event of a fault
Hazards 2 and 3: Conductive components in the 'overhead contact line zone' and in the 'pantograph zone'

Conductive components that are in the 'overhead contact line zone' and the 'pantograph zone' must be protected so as to prevent any danger to people from energisations resulting from fallen overhead contact line or pantographs.

Normal protection: Equalisation to return circuit

Where this is not practical, other measures may be considered instead:
• Barriers
• Protective screen connected to return circuit
• Locating out of range
• Restricting access
Hazard 4: Increase in potential in return circuit
Hazard 4 – Increase in potential in return circuit

Available permitted touch voltage is stipulated in NEK 900:

Duration up to 5 minutes:       65 V
Duration up to 0.3 seconds:     480 V
Duration up to 0.1 seconds:     785 V

This can be managed by:

• demonstrating that touch voltage arising from potential increase in the return circuit does not exceed the requirements (calculations, measurements)

• implementing measures to limit the danger arising from voltage increase in the return circuit
Hazard 4
Protection against return potential

- Use of equalisations
- Use of barriers
- Insulating standing surface from earth (e.g. dry gravel)
- Locating outside range
- Locating conductive components connected to the return circuit at arm's length from other conductive components
- Use of access control (trained personnel)
- Reduction of return potential by improving earth connections
Hazard 4 – About earth electrodes

Running rails are extremely good earth connections in themselves. As a worst-case scenario, the following resistances have been calculated:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Impedance (ohm)</th>
<th>Impedance (3 km) (ohm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16.7</td>
<td>2.5</td>
<td>35</td>
</tr>
<tr>
<td>50</td>
<td>4.0</td>
<td>35</td>
</tr>
</tbody>
</table>

Elements such as mast foundations that have been connected reduce resistance even further.

Extra earth electrodes will only affect the resistance against true earth to a limited degree
  - It is not usually expedient to have extra earth electrodes
Hazard 5
Current in conductors parallel to the return circuit

Thermal heating as a consequence of current in lineside conductive components

- Fences and crash barriers
- Handrails
- Water pipes and district heating pipes
- Cable guards
- Earthing conductors and neutral conductors for low-voltage network

If the component has been designed to take the current, this can be equalised to the return circuit at several points.

If the component has not been designed to take the current, there must be segmentation between each connection point.

Hazards resulting from a voltage difference at segmentation points or from disconnection must be assessed.
Hazard 5 – current in lineside conductive components – cable guards
Hazard 5 – current in lineside conductive components – low-voltage network
Hazard 6
Disruption to train detection

Train detection systems used by Jernbaneverket:

• Axle counters

• Track circuits
  – Double-insulated 95/105 Hz
  – Single-insulated 95/105 Hz
  – TI 21 audio-frequency track circuit (2–4 kHz)
  – FTG-S audio-frequency track circuit (4–17 kHz)
  – Level crossings: 10/50 kHz
Possible solutions:

- Equalisation via filter impedance
- Use of lineside earthing conductors
- Equalisation via voltage limiting devices (VLD, NEK 900)
- Insulation of equalised components from earth
Hazard 6 – track circuits

Earthing system and return current must not be configured so that a rail fracture can result in a safety failure.

This is a hazard if a rail fracture occurs in stations, and for this reason Jernbaneverket is preparing separate requirements for the design of return circuits in stations.

The example is one of three permitted principle solutions for stations with double-insulated track circuits.
Hazard 7: Lightning current

Lightning current is diverted to the return circuit via surge arresters.

This leads to a high increase in potential, and can break down the insulation in cables and conductors and start fires.

- Signalling systems are vulnerable

Measures to improve the immunity of vulnerable systems:

- Use of isolation transformers for conductors connected to running rails
- Length limits for cables connected to running rails
- Potential equalisation of cable guards and equipment for running rails

Measures to reduce emissions from surge arresters:

- Install impulse electrodes at surge arresters
- Connect surge arresters to return circuit via a large high-frequency impedance:
  - Filter impedance
  - Expedient configuration and connections
Interface between return circuit and network company earthing system

When components are connected, the following hazards may arise:

• Hazard 4: The potential from the return circuit can be transferred to the network company's earthing system.
  – This hazard is normally manageable
• Hazard 5: Where there are connections in several locations between the network company's earthing system and return circuit, the return current will go through the earthing system.
  – This hazard is manageable by ensuring that the design of the earthing conductors is adequate

The most practical solution is often to separate the return circuit from the network company's earthing system, but:

• Connection is permitted provided that agreement has been reached with the relevant network company about how to handle the hazard (NEK 900)
New Technical Regulations

Jernbaneverket's Technical Regulations for earthing contain requirements on how to handle the particular challenges posed by earthing on railway installations.

A complete revision of the Regulations has been published:

https://trv.jbv.no/wiki/Felles_elektro/Prosjektering_og_bygging/Jording_og_utjevning
Technical Regulations – what's new?

- Focus on hazards and risk assessments
- Less focus on specific methods
- Measures are to be used only if they are needed to manage the hazards. The use of measures must be justified

This means:
- Fewer earth connections and equalising connections than before
- More use of alternative protective measures
- Less focus on 'checking' where the return current goes

It also means:
- Greater need to calculate available voltage differences on specific sections
- More use of NEK 900 and NEK 440
  - Calculation assumptions are specified in the standards
Risk assessment

Regulations relating to electrical supply installations, section 2-2:

A risk assessment shall be carried out in order to identify risks in, and in relation to, the electrical installation. The risk assessment shall then be used as a basis for the choice of solution to address these risks. This shall be documented.

- Jernbaneverket therefore expects all solutions chosen for projects to be on the basis of a documented risk assessment.

- Choosing solutions in accordance with selected standards and the Technical Regulations is regarded as a sufficient risk assessment.
  - Where standards and the Technical Regulations indicate a number of solutions, the reason behind the choice must be documented.
Thank you for your attention