2 x 25 kV ac / 1 x 25 kV ac Grounding and Bonding

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Introduction

A 2 x 25kV ac/1 x 25kV ac electrification of a rail corridor means delivering power to the trains via an OCS, which is collected by roof-mounted pantograph current collectors on each train's locomotive or EMU vehicle. This type of system is common around the world.

There are various standards and guidelines worldwide that govern the G&B of electrified railways. Most of the electrified railways in North America, Europe and Asia have grounding and bonding systems designed in accordance with the Europeans Standard EN 50122-1. EN 50122-1 standards require the metallic structures within 4 m from the centre of the electrified track to be connected to the static wire.

The European standard EN 50122-1 is directly applicable to the G&B specifically of electrified rail transit systems that run on 2x25 kV ac and 1x25 kV ac.
In Canada, the Canadian railway electrification guidelines CAN/CSA-C22.3 no. 8-M91 (reaffirmed in 2003) suggests that every metallic structure within 10m from the outermost rail must be grounded to a local ground electrode and then bonded to the OCS static wire.
The main differences between the CAN/CSA C22.1; C22.3 – railway electrification guidelines and EN 50122-1 is the distance from the outermost electrified rail to the metallic structures that need be connected to the static wire.

1.0 Purpose

The purpose of this paper is twofold:

1. To provide a brief background on the design issues related to the G&B of the electrification of identified rail corridors
2. To outline an approach for the design and implementation of a safe G&B system with consideration of both EN 50122-1 and the applied local electrification standards

2.0 Scope

The scope of this paper is to:

- Minimize the possibility of persons (public and railway personnel) in the vicinity of grounded electrical facilities being exposed to unsafe touch and step potentials
- Provide the means to carry electric currents into the earth under normal and fault conditions without exceeding any operating and equipment limits or adversely affecting continuity of service

3.0 G&B issues

What is the most effective way of G&B that will minimize risk as well as minimize impacts to surrounding properties?

Often rail corridors have various properties that are close to the ROW (some within 4-10m), and thus could be effectively exposed to step and touch potential induced by the electrified railway. In this case, what does this mean for people or property owners living adjacent to (or even within 4-10m of the outermost rail) of the electrified railway, and most importantly what is the impact on the railway company?

4.0 OCL

OCL zone is the zone whose limits are not exceeded by a broken overhead contact line in the event of dewirement or by damaged pantograph or broken fragments occurred.

The objective of the protective provisions for electrical installations in the electrified corridor is focused to the following:

a. An operationally safe OCL zone
b. A protective zone of the areas just outside the OCL zone but within the right of way
c. A protective zone of the areas just outside the ROW

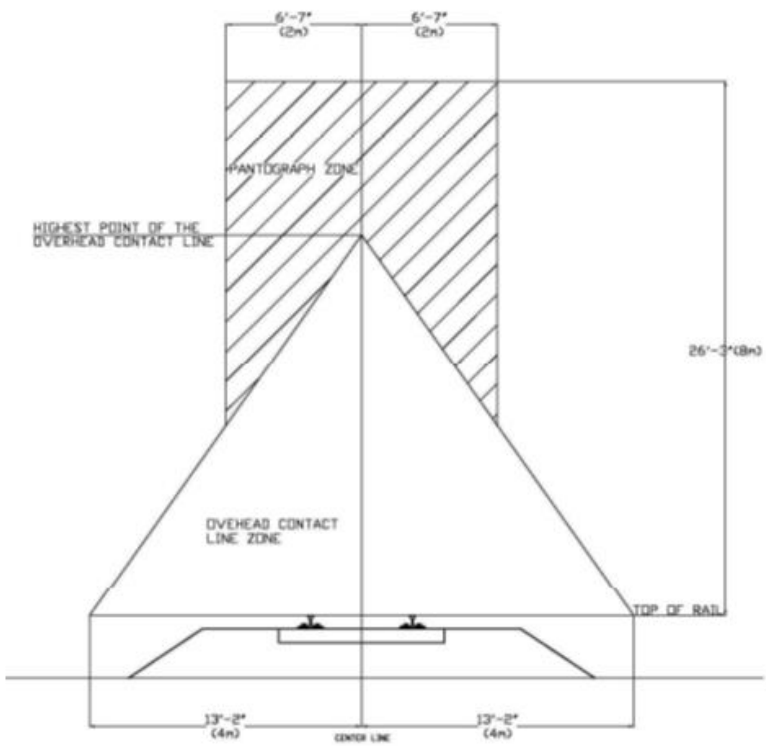
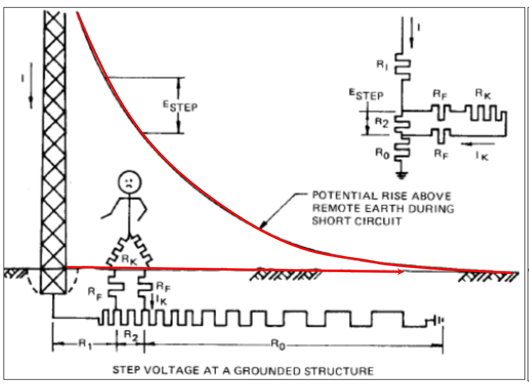


Figure 1. Overhead Contact Line Zone and Pantograph Zone

It should be noted that if an OCL breaks, then it will fall within the OCL zone (4m). The OCL and pantograph zones will be directly connected to the traction return and grounding system through the static wire, thus grounded.

5.0 Step and touch potential

Electrical potential is essentially the potential for electrical energy to travel through a surface and or a medium and induce an electrical shock to the person who has stepped on or touched the medium. The potential is determined by the resistivity of the medium in which it passes through. As shown in Figure 2 and Figure 3 below the zone of electrical potential is a value that needs to be determined by collecting more data to understand the resistivity of all mediums that the current may travel through (including that of a person or animal). This will help outline the potential rise above the surface of the ground (see red curve on Figure 2 and Figure 3) and effectively define the boundaries that the contractor will need to consider for G&B.



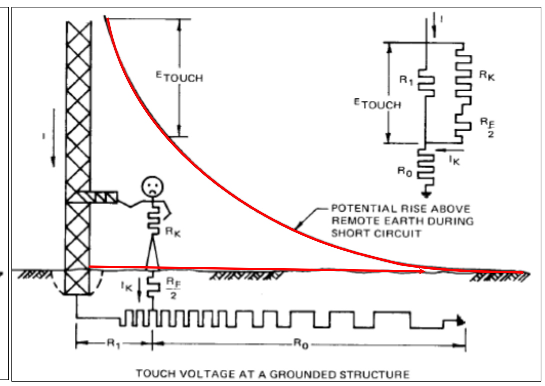


Figure 2. Step potential **Figure 3. Touch potential**

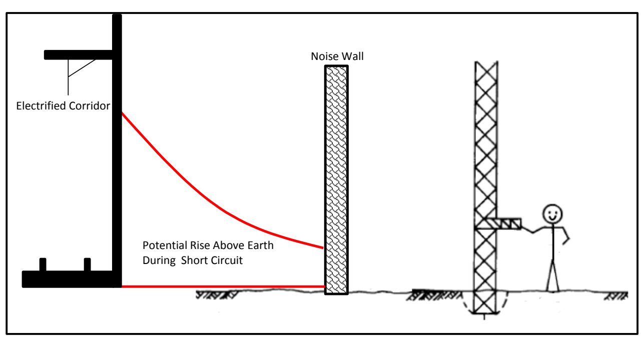


Figure 4. Noise wall barrier

Thus, the electrification contractor will need to measure the step and touch potential to determine whether there will be any need to implement additional G&B of metal structures or objects on adjacent properties to the ROW. As such, the contractor must determine how to best mitigate any harm which may occur within and outside of the railway's owned ROW. The most important consideration that needs to be made is how far outside the ROW of the railway must employ the mitigation strategy. By outlining a few set of key G&B rules the electrification contractor will be able to better understand where mitigation is required outside the ROW.

6.0 Key G&B rules

1. Everything in the 4m zone must be grounded back to the static wire (EN 50122-1)
2. All bridges must be grounded (including bridge barriers)
3. Any ROW, fences, and noise walls outside the 4m boundary may require additional local grounding
4. Locally ground all metallic structures within 4m and up to the defined ZOP (further studies are required on a case by case basis)
5. Buildings outside the ZOP - do nothing and assume local grounding is in place. An inspection procedure for verification purposes should be in place

With the exception of rule 4 above most can be accomplished by a railway company. Rule 4 requires additional work to be able to better define the ZOP.

7.0 Defining ZOP

It is recommended that at a minimum the design of the protective provisions of the OCL should meet the criteria outlined in EN 50122-1 (4m from centerline of outermost track) with the additional local grounding on case by case basis local building code.

For example, in Canada the CAN/CSA-C22.3 guideline no. 8-M91 (reaffirmed 2003) provides general guidelines for the operational and safety of the electrified railways (although it does not specify a 2x25kv system). Specifically:

- Zone 1: For the metallic structures within 10m from the nearest rail shall be grounded to a local ground electrode and then bonded to the rails
- Zone 2: For the metallic structures that are between 10m to 50m from the nearest rail shall be grounded to local ground electrodes, yet bonding to the rails is not required
- Zone 3: For the metallic structures that are between 50m to 250m from the nearest rail shall be grounded to local ground electrodes, yet bonding to the rails is not required

Caution should be paid on third party metallic structures outside the OCL zone of 4m. Specifically, any G&B connection outside the 4m zone which requires third party metallic structures to be connected directly to the OCS static wire should be reviewed carefully because that could increase step and touch potentials, as the third party's metallic structure would now be directly connected to the static wire and therefore people and animals will be exposed to the running rail voltage at all times. To effectively mitigate step and touch voltage in a vicinity of the electrified corridor it is suggested that EN 50122-1 should be used as the main reference towards the G&B design, and then examine case by case when and how the third party metallic structures and objects adjacent to the OCL zone will be connected to the OCS static wire.

7.1 ZOP case scenarios

A two scenario approach can be employed to better understand the ZOP

Scenario 1 – Corridor Study

- Complete a visual inspection of the corridor and compile an inventory of all metal items in the corridor
- Identify the areas where third party property owners are within 4-10m of the outermost tracks

Scenario 2 – Grounding and Bonding Study

- Conduct soil resistivity tests on the corridor's ROW where third party properties are within 4-10m away from the outermost electrified rail
- Develop potential rise above remote ground curves (ZOP) (refer to the Figure 2 and Figure 3 above) for each tested location
- Determine if the noise wall acts barrier to; and effectively eliminates, the step and touch potential between the ROW and third party metallic structures (refer to Figure 4)
- Using the potential rise curve (ZOP) calculate the step and touch potential outside of the railway corridor property and identify any areas where step and/or touch potential level is above the specified limits
- Conduct an inventory assessment of the areas where step and touch potential is identified to be higher than specified and make a record of all metallic structures, electrical installations, household utilities, outdoor pools, buildings, metal roofs, poles, fences fuel tanks, gas lines, and other facilities, utilities, metallic objects etc., that are located on those properties
- Analyze the inventory data for the selected areas and develop grounding and bonding mitigation plans that will bring the step and touch potential below the allowable limits
- Prepare a technical report, which outlines design solutions specific to the impacted properties, and provide a third party impact assessment for the construction and post-construction periods
- Develop cost estimating report which would outline construction and maintenance costs

8.0 Applied G&B railway standards around the globe

The following table depicts the standards followed by four big railway electrification projects around the world, namely in Europe (UK), USA, Canada and Trinidad (Caribbean). The diversity of projects selected is intentional so as to highlight the similarities in standard-setting across the board. Railway engineers and experts use a combination of local and international standards to ensure compliance by international best practice. In essence, the collective influence of national and international guidelines governs the G&B design and building of railway systems internationally. Please see more details below.

Network Rail (UK)	**California High Speed Train Project (CHSTP) (USA)**	**AMT (Canada)**	**Trinidad Rapid Rail Transit System (TTRTS)**
European Standard • BS EN 50122 part 1 • BS EN 50122-part 3 • BS EN 61140:2002; IEC 61140:2001 Protection against electric shock Common aspects for installation and equipment	• BS EN 50122-1:1998 specifying maximum permissible touch/accessible voltages during fault conditions • The Manual for Railway Engineering of the American Railway Engineering and	• CAN/CSA-C22.3 No. 8 M91 for G&B • AREMA standards • European standards • IEEE 80 for safety, fencing, and substation grounding	• EN 50121-1 1997: Railway application; Fixed installations; Protective provisions relating to electrical safety and earthing • EN 50122 part 1: Structure earthing;

• EN 61140 Protection against electric shock — Common aspects for installation and equipment • IEC 60364 Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions <u>UK Standards</u> • National Electricity Supply Rules • BS 7430 Code of Practice for Earthing • BS 767117th Edition Wiring Regulations • G59/1 Electricity Association Engineering Recommendation for 25kV ac electrified • GI/RT7077 Low Voltage Electrical Installation <u>CoP (Code of Practice)</u> • NR/SP/ELP/21085 Network Rail Earthing Standard • P24 AC Traction Supplies to British Rail	Maintenance of Way Association (AREMA) • Amtrak Electrified Territory Instructions for Cross-Bonding and Structure Grounding and Related Instructions dated February 15, 1991 • IEEE 1100: “Recommended Practice for Power Grounding Sensitive Electronic Equipment” • IEEE C62.41-2000: “IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits” • ANSI-J-STD-607-A “Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications” • IEEE 80: “Guide for Safety in AC Substation Grounding” • IEEE 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System” • IEEE 81: “Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System”		G&B of metallic components • IEEE Std. 80-2000 Guide for safety in ac substation grounding • IEC 60479: Effects of Current on Human Beings and Livestock – Part 1 General Aspects

9.0 Additional G&B examples

9.1 AMT Montreal Canada

AMT operates a 1x25 ac kV electrified rail system in Montreal. Specifically,

- AMT installed a ground conductor and a static wire (European concept, USA is not the same)
- AMT used portion of CAN/CSA-C22.3 no. 8-M91 (Reaffirmed 2003) and also AREMA standards and European standards (only within the ROW)
- AMT pays close attention to zone 1 and zone 2 (where it is within the ROW)
- AMT does not have residential structures in zone 1
- AMT requires grounding and bonding plans for zone 2 (10-30m of nearest rail). The residential is in Zone 2
- AMT grounded metallic structures in zone 1 and in zone 2 (where it is in the ROW).

9.1 Additional electrification G&B references

The following table (Table 1) depicts the application of EN 50122-1 standard by four railway electrification railways around the world, namely in Europe (UK) (Denmark), (France), USA, and Canada for designing protective provisions for electrical installations in the OCL and CCZ zones.

Table 1

UK – Network Rail	**USA – California High Speed Train**	**Denmark**	**France**
OCL zone is 5.2 m from the center line of the nearest rail	OCL zone is 4 m from the center line of the nearest rail	OCL zone is 5 m from the center line of the nearest rail	OCL zone is 4m from the center line of the nearest rail