1.0 INTRODUCTION

This guide covers the Design, Installation and Testing of grounding and bonding systems for outdoor 34.5 KV or higher voltage substations, whether installed by Vale Inco or a contractor.

Requirements of this guide shall be followed to ensure proper design of the grounding scheme for substations shown (indicative guideline for the design deliverable for substation grounding layout) in drawing 5331-2.2.0511 titled "H.V. Substation – Grounding & Bonding" the requirements of this guide shall be followed.

The following Vale Inco documents are to be used as references in conjunction with this guide and for preparation of deliverable drawings for Ground Grid Layout.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5331-02.01.511</td>
<td>Grounding Substation Fence</td>
</tr>
<tr>
<td>5322-01.02.511</td>
<td>H.V. Substation Elevation Views</td>
</tr>
<tr>
<td>5331-02.02.511</td>
<td>H.V. Substation – Grounding &amp; Bonding</td>
</tr>
</tbody>
</table>

These reference standards further refer to other standards for construction details. All standards referred to in this guide and in the above reference standards are available on the Vale Inco intranet site.

2.0 CODES AND REGULATIONS

For all references made in this guide for codes and regulations to be adhered to the latest issues, amendments and supplements must be applied unless stated otherwise.

CSA Canadian Standards Association
Vale Inco  Engineering Standard  Design Guide

OESC          Ontario Electrical Safety Code
OHSA          Occupational Health & Safety Act & Regulations for Mines & Mining Plants
CAN/CSA-M421-93  Use of Electricity in Mines

3.0   STANDARDS

For all references made in this guide to standards to be followed, the latest issues, amendments and supplements must be applied unless stated otherwise.

IEEE 80       Guide for Safety in Substation Grounding
IEEE 81       Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Ground Grid
IEEE 81-2     Guide for Measurement of Impedance and Safety Characteristics of Large Extended or Interconnected Grounding Systems
IEEE 367      Recommended Practice for Determining the Electrical Power Station Ground Potential Rise and Induced Voltage From a Power Fault
IEEE 525      Guide for Design and Installation of Cable Systems in Substations
IEEE 837      Standard for Qualifying Permanent Connections Used in Substation Grounding
IEEE 998      Guide for Direct Lightning Stroke Shielding of Substation

4.0   OBJECTIVES

The objectives for substation grounding are:

1. To maintain “step potential” and “touch potential” within safe values at all times for personnel working within and in the immediate vicinity of the substation.
2. To provide a safe means for dissipation of energy to earth in the event of surges and lightning strikes.
3. To ensure flow of sufficient current to earth during ground faults for protection devices to operate.
4. To provide stabilized ground reference potential for the facility electrical power system.

These objectives shall be achieved by maintaining a low resistance connection to earth in all seasons and to limit ground potential rise (GPR) under fault
conditions, for lightning strikes to the substation or to any conductor entering or leaving the substation and for any surge voltages on the system.

A grid ground resistance of maximum 1 ohm shall be achieved by design and verified by measurement after installation. This 1 ohm shall be achieved without use of building/structure foundation steel, cable sheaths or transmission line tower footings or sky wires. A lower resistance may be required to meet other design criteria.

5.0 GROUND GRID DESIGN CRITERIA

The basis for achieving the design objectives will be dependent on the following site-specific information.

1. Soil resistivity
2. Maximum and minimum ground fault current
3. Fault clearing time

5.1 Soil resistivity

Once the substation site has been identified, the soil resistivity at the location shall be established by measurement. The Wenner method as described in IEEE 81 shall be used.

5.2 Ground fault currents

This information will be available from Vale Inco Power Department. The fault level at the location of the proposed substation or the fault level at 69 KV at the sending end substation will be made available. In case of the latter the fault levels at the substation being designed will have to be calculated.

5.3 Fault clearing times

This information will be available from the protection co-ordination study for the subject substation. If it is not available then 0.5 sec time as per CEC shall be considered.

6.0 GROUND GRID CALCULATIONS

Once the soil resistivity readings have been obtained and the fault level calculations completed, the designer must decide on the size, depth of burial and the spacing between grid conductors as well as number and location of ground rods.
6.1 Method of calculations

The preferred software package is CDEGS from SES. A minimum of 2 layers model for soil shall be considered. The capabilities of the Autogrid Pro module of the software are acceptable as a minimum.

If any other software program is proposed for running the calculations then equivalence to the preferred software must be demonstrated. On approval from Vale Inco the alternate software may be used.

Longhand calculations performed by an experienced professional engineer are also acceptable.

6.2 Calculation results

The report for the design calculations shall include the following data:

1. Input parameters (resistivity readings, fault levels and fault clearing times)
2. Safe touch and step potentials
3. The maximum step potential
4. The maximum touch potential
5. Temperature rise of grid conductors (this should be lower than maximum permitted for compression type fittings for copper conductors)
6. Touch and step potentials on the outside of the substation fence.
7. Minimum number of rods and their locations.
8. Graphs for touch and step potential generated by the software (not required in case of hand calculations)
9. The completed design shall be checked by calculation for safe touch and step potentials in winter conditions by incorporating a frozen top layer in the soil model.

7.0 FINAL RESISTANCE READING

After the completion of the ground grid installation the resistance of the grid shall be measured as per procedures given in IEEE 81.

8.0 OTHER DESIGN CONSIDERATIONS

It is understood that there are many other factors that can have an influence on substation grounding; the following issues will be treated on a case-by-case basis as applicable.

1. Soil treatment & chemical rods
2. Seasonal variations in ground resistance values
3. Fence bonding
4. Corrosive soil
5. Equipment grounding & bonding
6. Grounding of reinforcing in concrete
7. Power cables and over head lines in and out of substation
8. Communication/signalling cables in and out of substation
9. Remote ground grid
10. Lightning protection for substation

8.1 Soil treatment

It may be a consideration to add soil treatment of sub station soil or to consider chemical rods as an alternative to achieve the desired grid resistance value.

To consider soil treatment a search of professional literature on the subject shall be conducted to identify the most suitable treatment. Lifetime cost analysis shall be carried out in comparing the proposed treatment against chemical type rods. This procedure shall be carried out after approval by Vale Inco.

8.2 Seasonal variations

The design of the ground grid shall take into account the effects of soil freezing in winter season.

8.3 Fence bonding

All fence bonding shall be as per CEC Section 36-310 and the reference drawings. The grid shall extend 1 meter beyond the fence. If the gates in substation fence open outward then the grid shall be extended one meter beyond the maximum swing point of the gate at that location.

If the control building is located within the substation fence and it has a basement cellar for cabling, mesh potential in the basement shall also be checked for personnel safety.

8.4 Corrosive soil

The soil at the substation location shall be evaluated for corrosive properties. If it is determined to be detrimental to grounding material used then alternate materials shall be proposed or cathodic protection shall be designed as a part of the grounding grid.

8.5 Equipment grounding & bonding

All equipment grounding and bonding shall be as per CEC Section 36 and generally as per reference drawings indicated in this guide.
8.6 Grounding of reinforcing in concrete

Concrete reinforcing steel may be used as a part of the grounding grid when approved by Vale Inco.

8.7 Power cables in and out of substation

Power cables having shielding and armour shall have the shields and armours grounded at both ends unless special requirements prevent this.

For single core cables, if shields are grounded at one end only, it must be ensured that induced shield voltages do not exceed 25 V. See IEEE 525.

8.8 Communication/signalling cables in and out of substation

Communication and instrumentation cables are a particular concern. For shielding and grounding of instrumentation and control cables see IEEE Std. 1050. In case of cables used for SCADA applications see IEEE Std. C37.1-1987. In addition the general rules set forth in standards should be tempered by manufacturer’s recommendations.

In general such cables will have their shields grounded at one point only in order to avoid noise signals due to circulating currents that may result from ground potential rise being different at different grounding points.

8.9 Remote ground grid

The practice of using remote ground grids is highly discouraged and shall only be considered as the last resort action in the event that computations considering all other measures (using foundation reinforcements, grid embedded in concrete or other treated soil, chemical rods etc.) to achieve the desired grid resistance fail.

When such grids are installed they should be tied together by a minimum of 2 4/0 copper stranded conductor buried at a depth of 36 inches and installed generally as per Standard 5316-02.01.610.

Usage of remote grounds introduces hazards of its own and additional safety measures like warning signs and barrier posts will be required. The route of the buried conductors should be marked with well-placed stakes.
The remote grid must be clearly identified with warning signs (DANGER – REMOTE GROUND). The location of remote ground and interconnecting conductors must be marked on As Built mark ups.

8.10 Interface with Lightning Protection for substation

Lightning protection for substations is covered in a separate standard. Since the two issues are related it may be noted that lightning whips and arrestor leads are to be connected to dedicated ground rods by the shortest possible connection without any sharp bends. These rods shall then be bonded to the substation ground grid.

9.0 OTHER RECOMMENDATIONS

9.1 Rock layer

A layer of ¾” crushed high resistivity rock covering the substation area to a depth of 6” must be installed. The material must extend at least 1 meter beyond perimeter of fence as per CEC Section 36.

9.2 Transferred voltages

Transferred voltages are a concern that may be overlooked in many substation installations. A case in point is the connection of the plant security fence to the substation fence. Section 36 of the CEC clearly indicates that the two fences must be safely isolated.

Transferred voltages are also a problem as it relates to using portable tools fed from energized substation. This problem is to be reviewed for each and every substation.

10.0 DELIVERABLES

- Calculation report as per clause 6.2
- Grounding Layout Drawings (Standard Drawing 5331-02.02.511 shall be used as a reference guide for preparation of ground grid layout drawing)
- Final Grid Resistance test value

END OF STANDARD 5322-01.01.0111