Earthing Safety in Design

What to be aware of when modifying a potentially hazardous substation

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Safety by Design vs. Safety in Design ?

SbD - Safety principles built into the final design concept.

SiD – Inclusion of safety principles within the entire design/installation process.

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Overview

- Earthing Background
- SiD Earthing Example: Gardiner (K) Substation
- Hazard Mitigation Examples

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Earthing Background

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What is the purpose of Earthing?

- Safety of personnel
- Protection operation
- Conductor current carrying capacity
- Consistent Z for system lifetime

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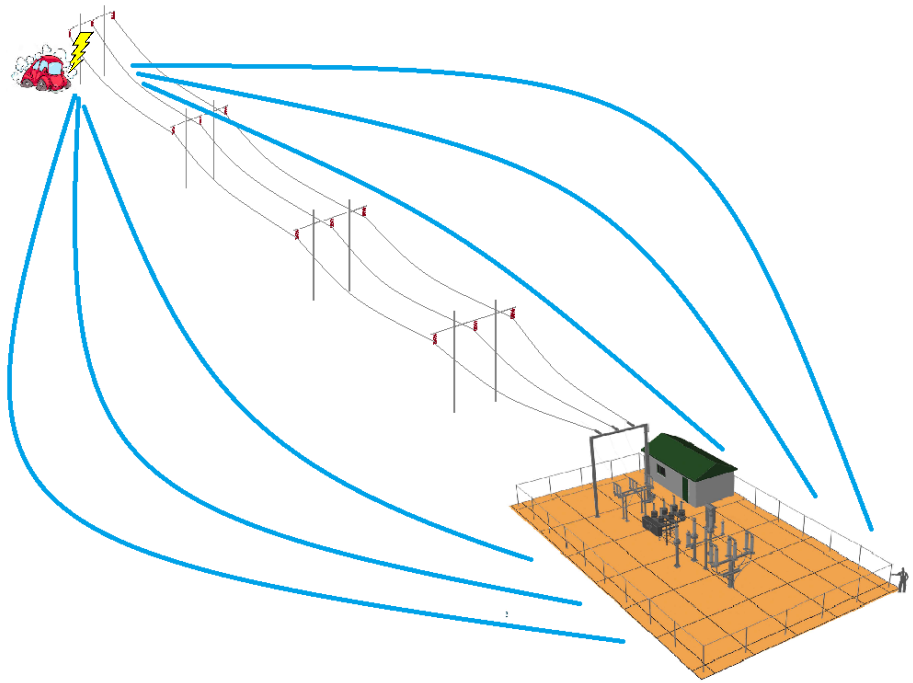
Earth Fault Conditions



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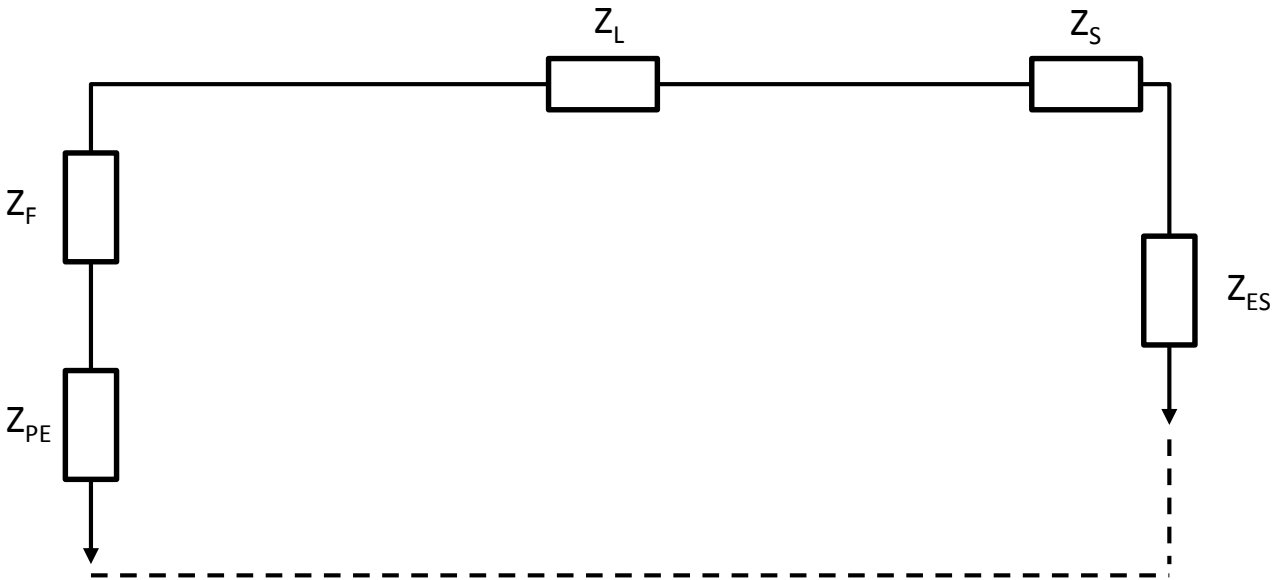
Fault Equivalent Circuit



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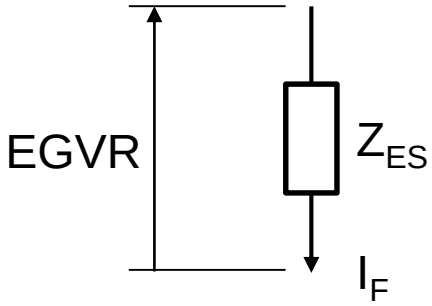
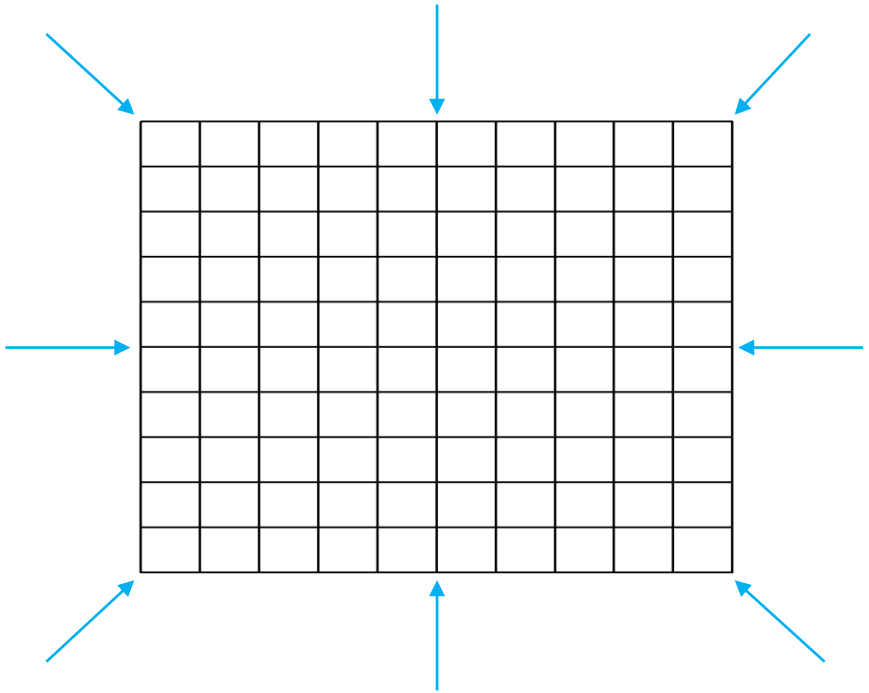
Earth Grid Voltage Rise

$$EGVR = I_F . Z_{Earth\ System}$$





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Earth Grid Voltage Rise

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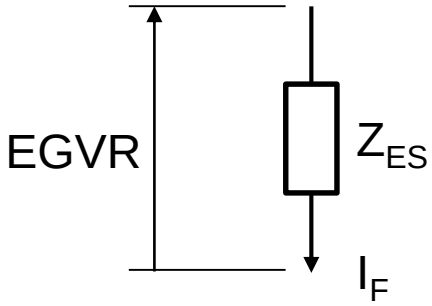

Example:

I_F = 1,000 A

$Z_{Earth\ System}$ = 1 Ω

$EGVR$ = 1,000 V

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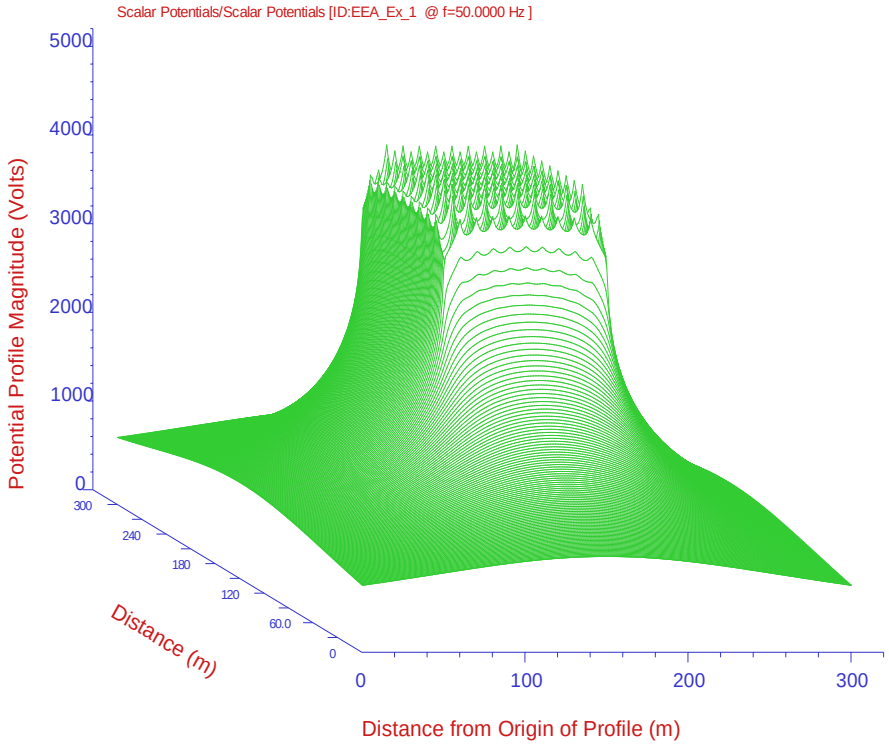
Earth Potential Rise

- Earth Grid Voltage Rise

  $EGVR = I_F . Z_{Earth\ System}$

- Earth Potential Rise

  Potential of earths surface at any point relative to remote earth



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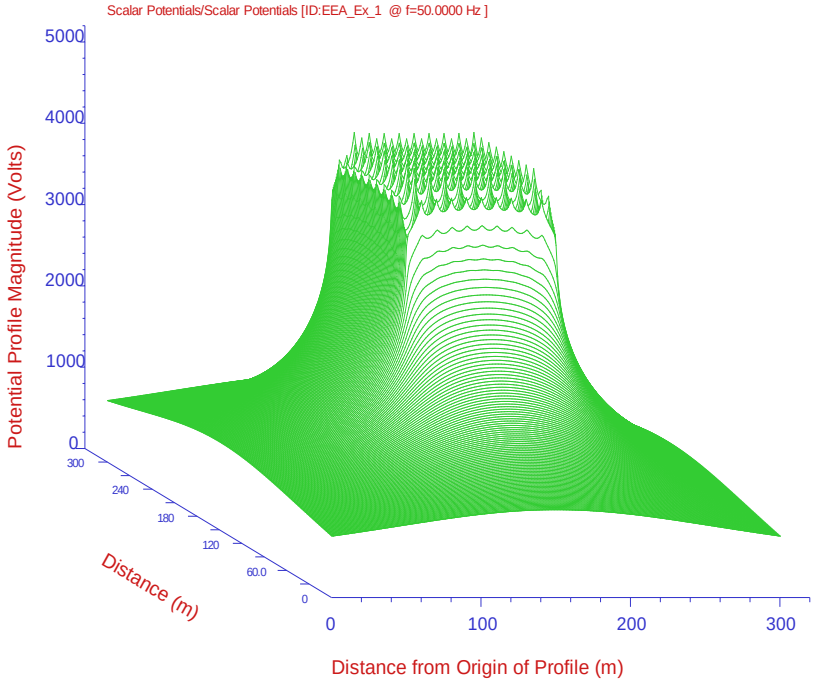
Earth Potential Rise



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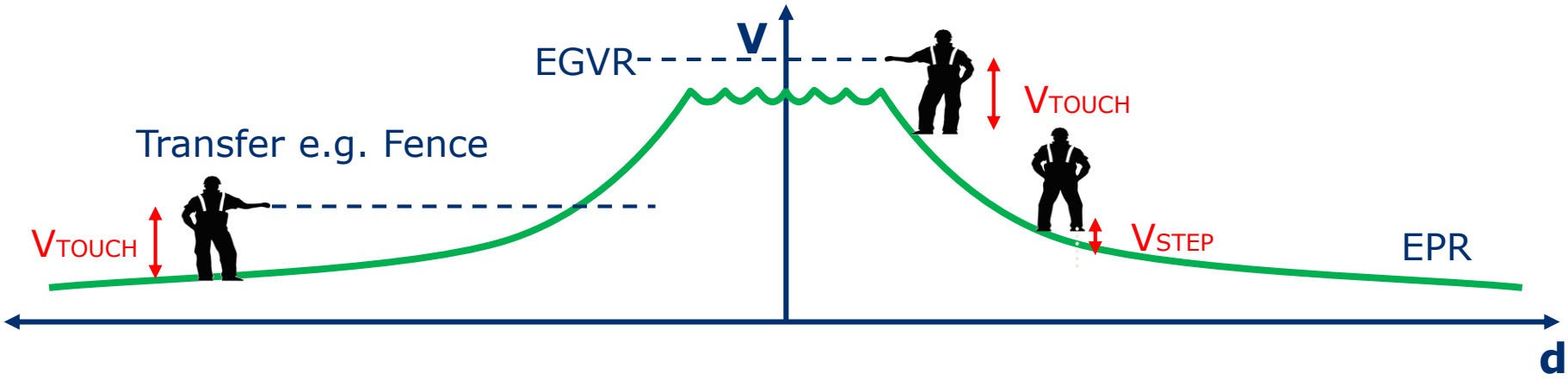
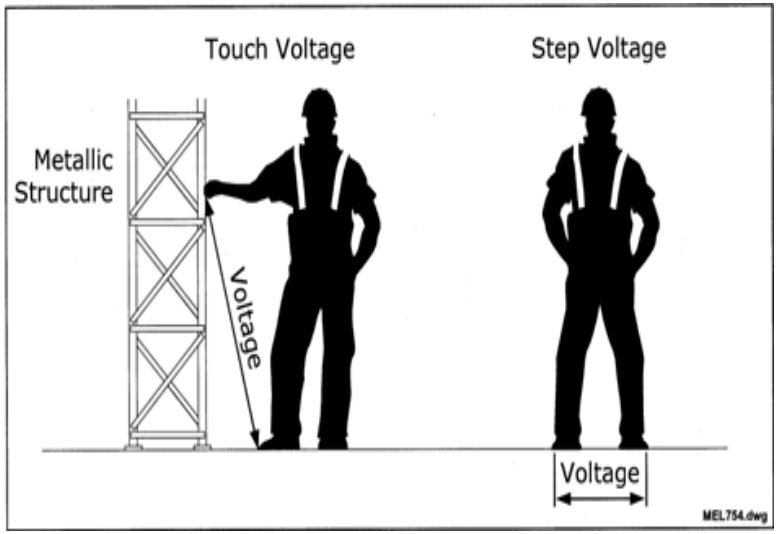
Why is this of any concern?

- Safety of Personnel



Touch & Step Voltages



- Tolerable Voltage Limits
  - IEC 60479 or IEEE80
  - Based on fault clearing time and soil resistivity

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SiD Example: Gardiner (K) Substation

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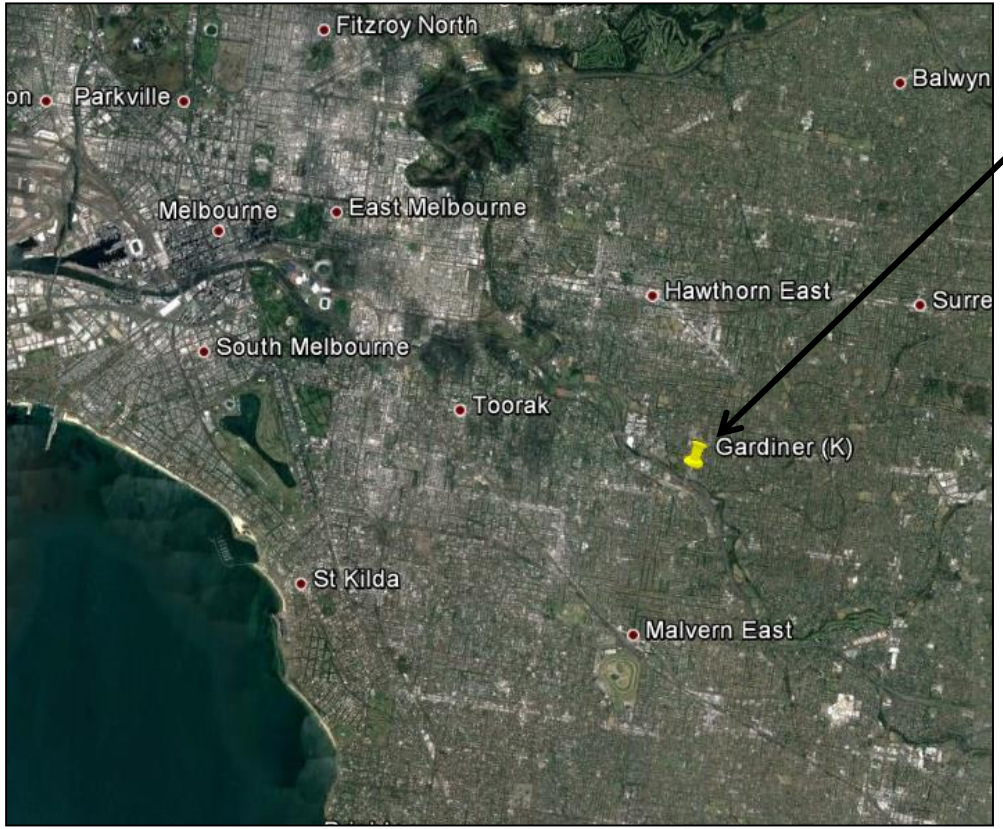
Gardiner (K) Substation



- 66/11kV Zone Substation
- Two 66/11 kV Transformers
- 11 kV Capacitor Bank
- 11 kV Harmonic Filter (To be installed)

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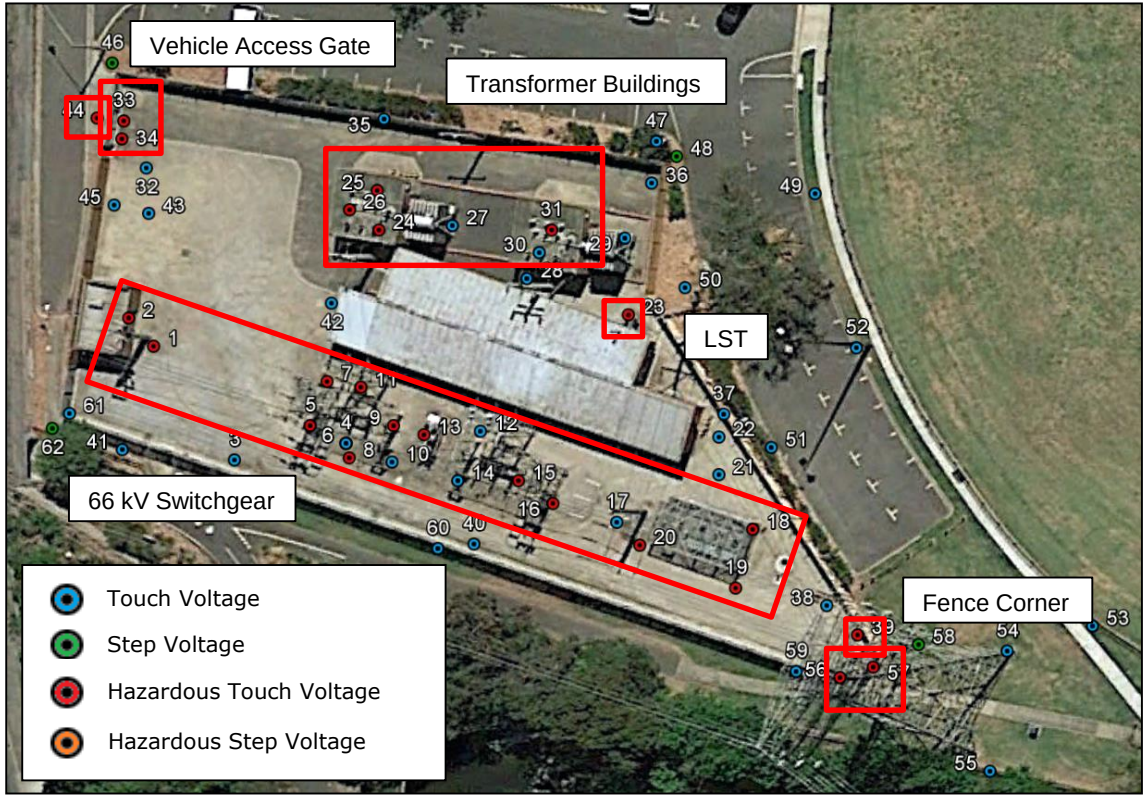
Pre-Construction Testing



- Earth grid injection testing (August 2015)
- EGVR = 1,055 V
- 3 Public Access Hazards
- 22 Restricted Access Hazards

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Initial Recommendations

1. Installation of asphalt near the south east corner of the outer substation security fence and the vehicle access gate (PA).
2. Install non-conductive surfacing within the transformer buildings (RA).
3. Install crushed rock surfacing within the switchyard (RA).
4. Transfer hazards could be present during the construction phase of the harmonic filter. A **Safety in design** study should be completed.

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Harmonic Filter SiD Study

- Identify potential transfer hazards:
  1. New earth grid conductors
  2. Temporary power supply
  3. Long metallic objects (e.g. fence sections)
- Model each case within CDEGS™ Software
- Provide Recommendations

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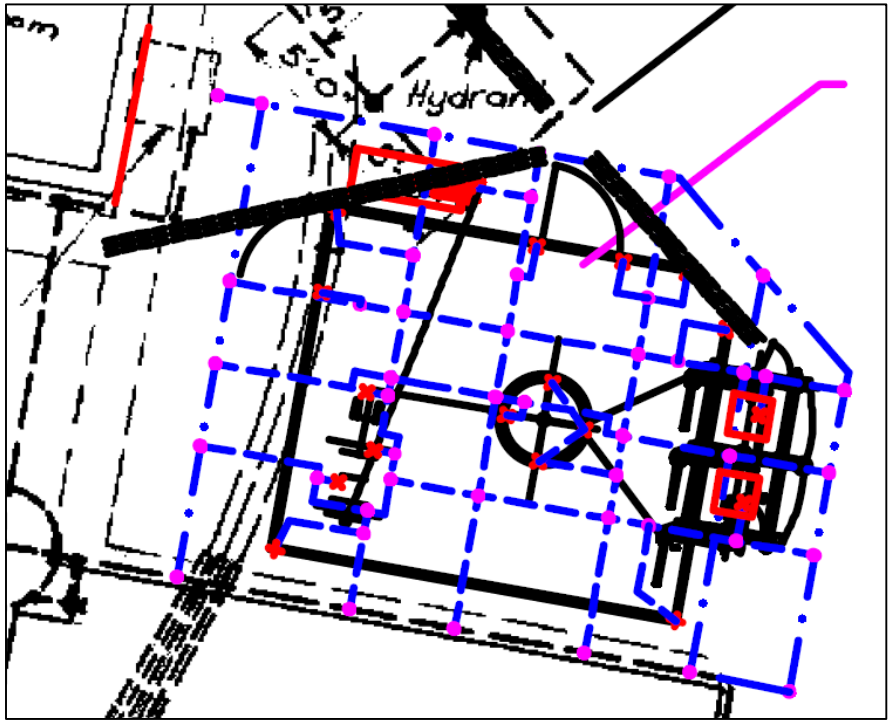
1. New Earth Grid Conductors



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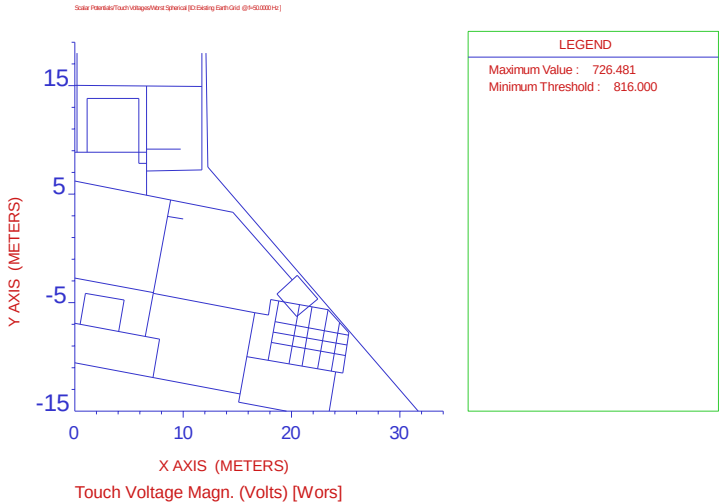
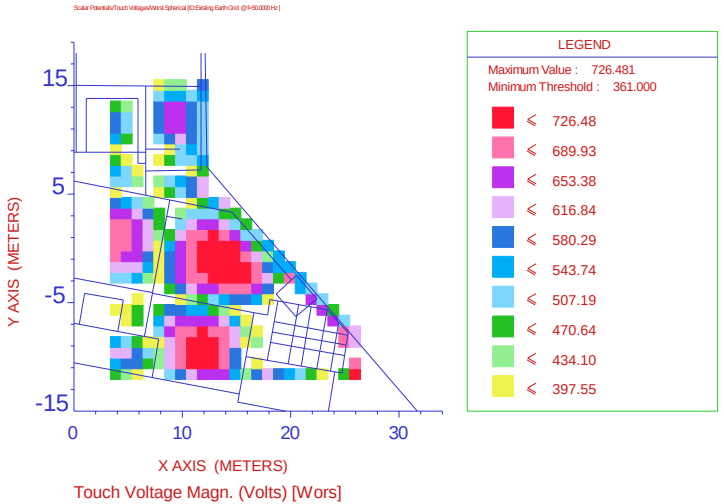
1. New Earth Grid Conductors

Crushed Rock - Safe



Touch Voltage Magn. (Volts) [Wors]

Natural Ground - Hazardous



Touch Voltage Magn. (Volts) [Wors]

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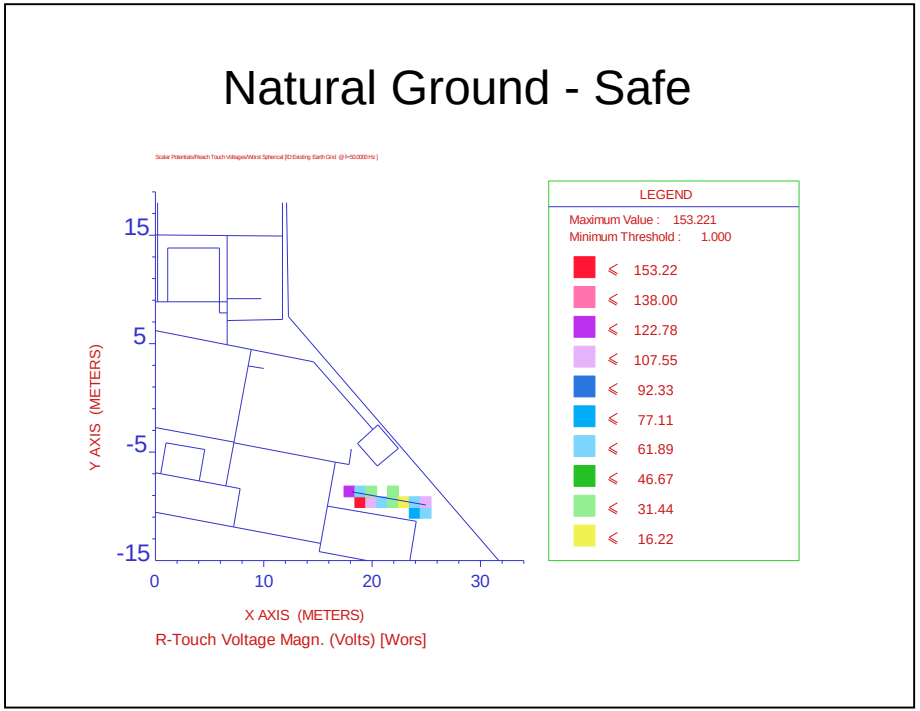
1. New Earth Grid Conductors



- Longest conductor modelled (worst case)
- Non-hazardous touch voltage (≈ 153 V)
- $V_{TL\_RA\_NG} = 361\ V$
- Can install in isolation of main earth grid

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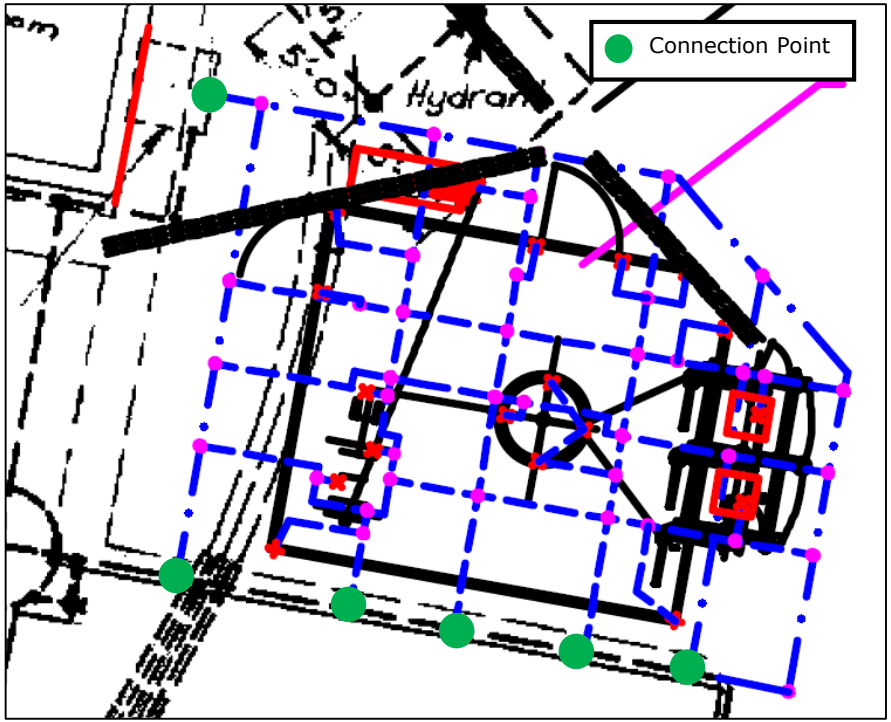
1. New Earth Grid Conductors



Connection Procedure:

1. Harmonic filter earth grid installed in isolation.
2. Wear insulating gloves.
3. Temporary earth link for each connection.
4. Align and make CADWELD connection.

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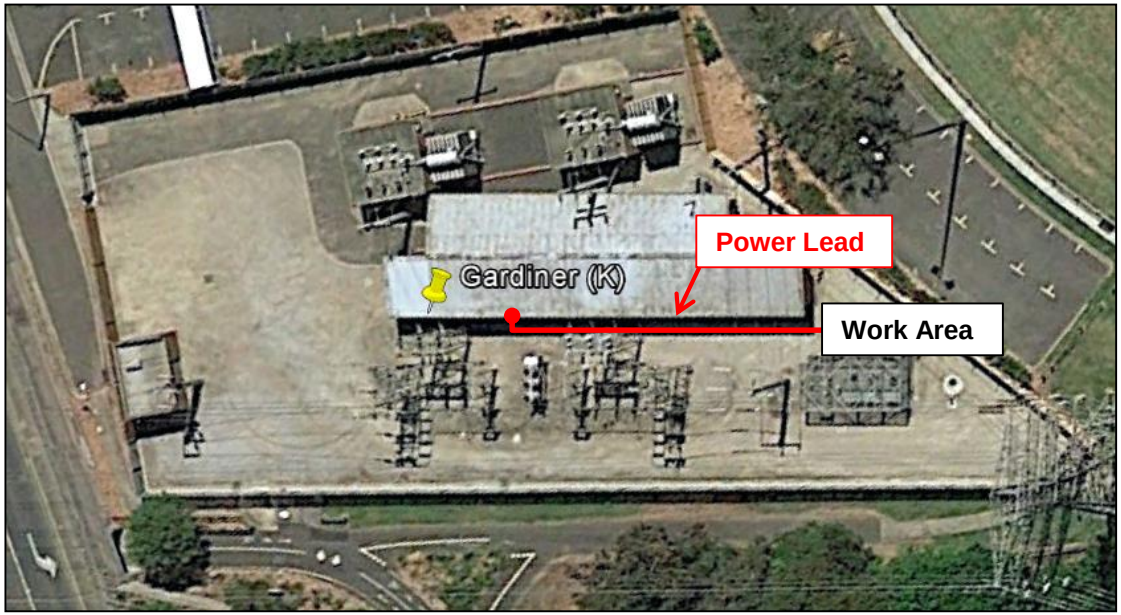
2. Temporary Site Power Supply



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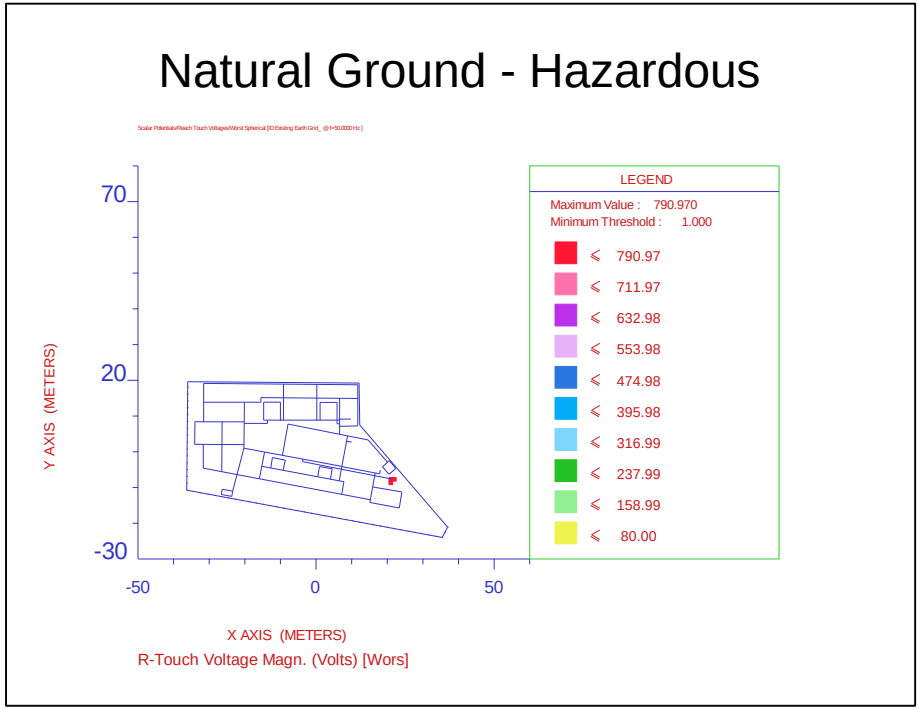
2. Temporary Site Power Supply



- Hazardous touch voltage modelled on earth lug (≈ 791 V).
- $V_{TL\_RA\_NG} = 361\ V$
- Need to isolate the power lead earth.

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2. Temporary Site Power Supply

Solutions:

1) Battery operated tools

2) Double insulated tools

3) LV isolation transformer

4) Portable generator

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3. Long Metallic Objects

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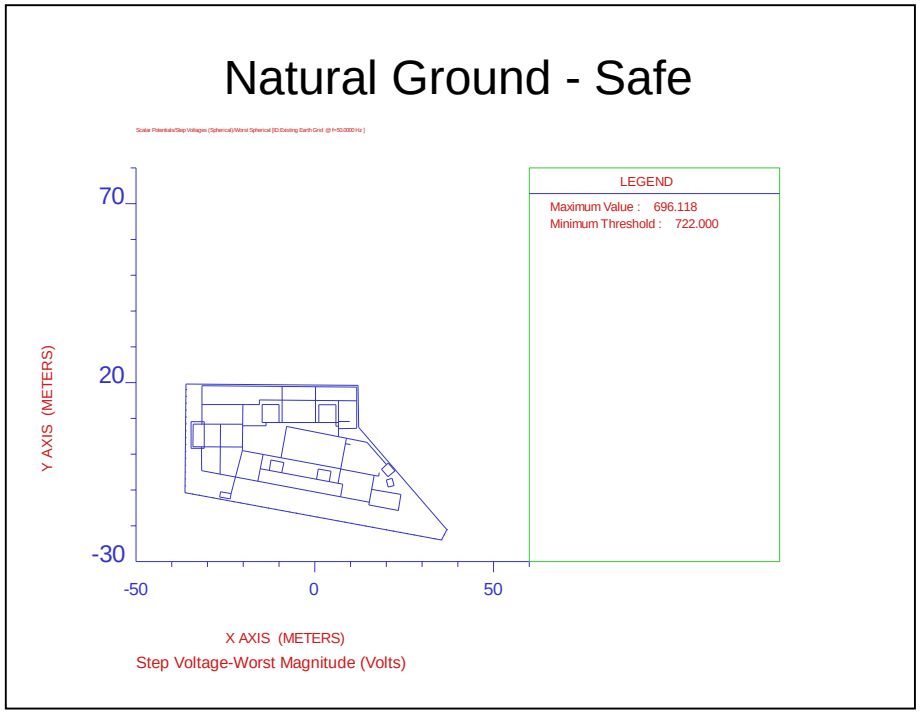
3. Long Metallic Objects

$$V_{TL\_RA\_NG} = 361\ V$$

$$2 \times V_{TL\_RA\_NG} = 722\ V$$

3. Long Metallic Objects



- $2 \times V_{TL\_RA\_NG} = 722\ V$
- Hazardous voltages modelled when step stride increased from 6m to 7m.
- Recommendation to carry metallic objects less than 6m only.

Mitigation Installed: Gardiner (K) Substation

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Asphalting (Vehicle access gate)

$V_{TM} = 342\ V$

$V_{TL\_PA\_C} = 128\ V$

$V_{TL\_PA\_A} = 1{,}506\ V$

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Asphalting (SE Security Fence Corner)

$V_{TM} = 363\ V$

$V_{TL\_PA\_NG} = 151\ V$

$V_{TL\_PA\_A} = 1{,}506\ V$

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Transformer Building Floor

$V_{TM} = 264\ V$

$V_{TL\_RA\_C} = 173\ V$

Isolated

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Crushed Rock Surfacing

$V_{TM} = 456\ V$

$V_{TL\_RA\_NG} = 204\ V$

$V_{TL\_RA\_CR} = 659\ V$

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Summary

- Explained the key difference between SbD and SiD
- Earthing Background
- SiD Example: Harmonic Filter Installation
- Hazard Mitigation Examples

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Questions?