

OWNER

# Station Grounding and Bonding Design

Calculation



Document No.: [REDACTED] ELE-CAL-005

Rev. A, Issued for Review

Date: September 29, 2026

Project: [REDACTED] [REDACTED]



TORUS

[REDACTED], [REDACTED] County, [REDACTED]

# ISSUE SUMMARY AND APPROVAL

This page records each issue of ELE-CAL-005. The preparer, reviewer and approver sign for each revision.

| Rev. | Date       | Issue purpose     | Description |
|------|------------|-------------------|-------------|
| A    | 2026-09-29 | Issued for Review | First issue |
|      |            |                   |             |
|      |            |                   |             |

## Contributors

| Rev. | Discipline | Prepared by | Reviewed by | Approved by |
|------|------------|-------------|-------------|-------------|
| A    | Electrical |             |             |             |
|      |            |             |             |             |

# CONTENTS

|    |                                                            |    |
|----|------------------------------------------------------------|----|
| 1. | OBJECTIVE.....                                             | 1  |
| 2. | METHODOLOGY .....                                          | 1  |
| 3. | DESIGN INPUTS.....                                         | 1  |
| 4. | ASSUMPTIONS.....                                           | 2  |
| 5. | REFERENCES .....                                           | 3  |
| 6. | CALCULATION.....                                           | 3  |
|    | 6.1. GROUNDING SYSTEM LAYOUT.....                          | 3  |
|    | 6.2. GRID CURRENT.....                                     | 4  |
|    | 6.3. CONDUCTOR SIZE.....                                   | 4  |
|    | 6.4. TOLERABLE TOUCH AND STEP VOLTAGES.....                | 5  |
|    | 6.5. GRID RESISTANCE AND GROUND POTENTIAL RISE.....        | 5  |
|    | 6.6. MESH AND STEP VOLTAGES, ELECTRICAL AREA.....          | 6  |
|    | 6.7. MESH AND STEP VOLTAGES, PROCESS AREA.....             | 7  |
|    | 6.8. TOUCH VOLTAGE OUTSIDE THE FENCE.....                  | 7  |
|    | 6.9. NEC ARTICLE 250 REQUIREMENTS .....                    | 7  |
|    | 6.10. EQUIPMENT GROUNDING AND BONDING .....                | 8  |
|    | 6.11. INSULATING JOINTS .....                              | 9  |
|    | 6.12. CROSSINGS OF BURIED PIPE .....                       | 10 |
|    | 6.13. SIGNAL REFERENCE GROUNDING AND SURGE PROTECTION..... | 10 |
| 7. | RESULTS AND CONCLUSIONS .....                              | 10 |

FIGURES AND TABLES

Figure 7-1. Calculated Touch and Step Voltages as a Share of the Tolerable Limits .....11

Table 3-1: Design Inputs.....1

Table 6-1: Grounding System Quantities .....4

Table 6-2: Tolerable Touch and Step Voltages, 50 kg, 0.5 s.....5

Table 6-3: Equipment Grounding Connections.....8

Table 6-4: Grounding Conductor Crossings of Buried Pipe.....10

Table 7-1: Grounding Check Summary .....11

APPENDICES

APPENDIX A. GROUNDING AND LIGHTNING PROTECTION PLAN .....13

## 1. OBJECTIVE

This calculation designs the grounding system for the . It sizes the grid conductors, confirms that the touch and step voltages produced by a utility ground fault at transformer XF-101 stay within the IEEE 80 tolerable limits inside and outside the fence, and sets the equipment grounding, bonding, static grounding, insulating joint and surge protection requirements that the grounding plan in Appendix A shows.

## 2. METHODOLOGY

The only fault that drives current into the earth at this station is a single line-to-ground fault on the utility's 12.47 kV primary at XF-101. Faults on the 480 V and 208 V systems return to the source on the equipment grounding conductors and do not raise the potential of the station against remote earth, so they are covered by the conductor sizing in ELE-CAL-004 and not repeated here.

TORUS laid out the grounding system first and then analysed it with the IEEE 80-2013 method. The system has four parts. A 4/0 perimeter loop runs 3 ft outside the fence, and the fence is bonded to it so that a person touching the fence from outside stands over buried copper. A closer-meshed grid covers the electrical area around XF-101, B-102 and G-101, where the fault enters the ground. A ring with two cross conductors covers the process area and gives every piece of equipment a short tap. Ties join the ring to the perimeter loop at seven points.

The grid resistance follows Sverak's equation. Mesh (touch) and step voltages follow the IEEE 80 closed-form equations. These equations assume a uniform grid; the process area has coarse meshes of unequal size, so TORUS also calculated the earth surface potential numerically. The numerical model divides every conductor and rod into line elements carrying equal leakage current per unit length, adds the image in the ground surface, and gives the surface potential on a 2 ft grid inside the fence and 1 m outside it. Where the two methods give different touch or step voltages, the larger governs.

The grounding electrode, grounding electrode conductor and equipment grounding conductor requirements of NEC Article 250 were then checked against the design.

## 3. DESIGN INPUTS

The inputs in Table 3-1 govern the calculation.

Table 3-1: Design Inputs

| Input                     | Value                                                    | Source                |
|---------------------------|----------------------------------------------------------|-----------------------|
| Soil resistivity, uniform | 15 $\Omega\cdot\text{m}$ (1,500 $\Omega\cdot\text{cm}$ ) | GEN-DB-001, HOLD H-08 |

| Input                                          | Value                                                        | Source                                            |
|------------------------------------------------|--------------------------------------------------------------|---------------------------------------------------|
| Utility primary system                         | 12.47 kV grounded wye, multigrounded neutral                 | Assumed, HOLD H-10                                |
| Line-to-ground fault at XF-101 primary, $3I_0$ | 5,000 A                                                      | Assumed, HOLD H-10                                |
| Current split factor $S_f$                     | 0.50                                                         | Assumed, conservative for a multigrounded neutral |
| X/R ratio at the fault                         | 10                                                           | Assumed, HOLD H-10                                |
| Fault duration $t_f$ and shock duration $t_s$  | 0.5 s                                                        | Utility protection, assumed                       |
| Conductor sizing duration $t_c$                | 1.0 s                                                        | Backup clearing, conservative                     |
| Surface layer, general pad                     | 6 in dense-graded aggregate, 1,000 $\Omega\cdot\text{m}$ wet | CIV site grading; resistivity assumed             |
| Surface layer, electrical area                 | 4 in clean crushed rock, 3,000 $\Omega\cdot\text{m}$ wet     | Specified by this calculation                     |
| Grid burial depth $h$                          | 2 ft (0.61 m)                                                | This calculation                                  |
| Grid conductor                                 | 4/0 AWG bare soft-drawn copper, $d = 0.528$ in               | This calculation                                  |
| Ground rods                                    | 5/8 in x 10 ft copper-clad steel                             | This calculation                                  |
| Equipment and fence layout                     | Plot plan                                                    | MEC-DWG-001                                       |

## 4. ASSUMPTIONS

1. The soil is uniform at 15  $\Omega\cdot\text{m}$ . A two-layer model from the Wenner survey will replace it; a more resistive upper layer would raise the grid resistance and must be rechecked. *Verification required (HOLD H-08).*
2. The utility primary fault current, X/R ratio and clearing time are as listed. *Verification required (HOLD H-10).*
3. Half the fault current returns through the earth ( $S_f = 0.5$ ). A multigrounded neutral normally carries more than half, so this is conservative. No credit is taken for the neutral in the grid resistance.
4. The wet resistivity of the pad aggregate is 1,000  $\Omega\cdot\text{m}$ . Dense-graded aggregate with fines can be lower than washed rock. *Verification required: resistivity test of a sample before construction.*
5. A 50 kg body weight is used for tolerable voltages. The station is unmanned and fenced, but the lighter body gives the lower, more conservative limit.
6. The numerical surface-potential model assumes uniform leakage along the conductors. It understates current at the grid edges and overstates it in the interior, which makes it reliable for interior meshes and conservative for the fence.

---

## 5. REFERENCES

---

1. IEEE Std 80-2013, IEEE Guide for Safety in AC Substation Grounding.
2. IEEE Std 142-2007, Recommended Practice for Grounding of Industrial and Commercial Power Systems.
3. IEEE Std 1100-2005, Recommended Practice for Powering and Grounding Electronic Equipment.
4. IEEE Std 837-2014, Qualifying Permanent Connections Used in Substation Grounding.
5. NFPA 70, National Electrical Code, 2023 Edition, Articles 242, 250 and 501.
6. NFPA 77, Recommended Practice on Static Electricity, 2019 Edition.
7. API RP 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents, 8th Edition (2015).
8. AMPP SP0169-2013, Control of External Corrosion on Underground or Submerged Metallic Piping Systems.
9. GEN-DB-001, Basis of Design.
10. ELE-CAL-004, Cable Sizing, Voltage Drop, Short Circuit, Protection and Arc-Flash Screening.
11. ELE-CAL-006, Lightning Risk Assessment and Protection Design.
12. CP-CAL-001, Cathodic Protection Design; CP-DWG-002, Cathodic Protection Details.
13. MEC-DWG-001, Plot Plan.
14. ELE-DWG-004, Grounding and Lightning Protection Plan (Appendix A); ELE-DWG-007, Typical Installation Details.

---

## 6. CALCULATION

---

### 6.1. GROUNDING SYSTEM LAYOUT

The perimeter loop encloses 256 ft by 206 ft. The electrical-area grid spans X 176 to 253 ft and Y -3 to 44 ft with 6 north-south and 4 east-west conductors. Its lines were placed in the gaps between the transformer pad, the generator enclosure and B-102 rather than on a uniform pitch, because a conductor under a foundation cannot be repaired and is easily cut during construction; the largest spacing that results is 28.5 ft. The process ring runs at Y = 34, 168 ft and X = 16, 236 ft, with cross conductors along the main cable trench at Y = 83 ft and at X = 130 ft. Laying the Y = 83 ft conductor in the cable trench costs almost nothing and halves the process meshes. The ANT-201 antenna monopole has its own small ring with four rods, bonded to the process ring. No grid conductor passes under an equipment footprint. Table 6-1 summarizes the quantities.

**Table 6-1: Grounding System Quantities**

| Item                                                                          | Quantity            | Remarks                      |
|-------------------------------------------------------------------------------|---------------------|------------------------------|
| 4/0 AWG bare copper: grid, loops, ties, gate crossings, B-102 and XF-101 taps | 2,684 ft            | Net route length             |
| 2/0 AWG bare copper: major equipment taps and mast bonds                      | 537 ft              | Includes 5 ft per connection |
| #2 AWG tinned copper: minor taps, poles, fence                                | 520 ft              | Includes 5 ft per connection |
| Ground rods, 5/8 in x 10 ft                                                   | 49                  | 6 in test wells              |
| Copper surface in contact with soil                                           | 511 ft <sup>2</sup> | Carried to CP-CAL-001        |

Note 1: The material take-off adds a 10 % allowance to conductor lengths.

## 6.2. GRID CURRENT

The decrement factor accounts for the DC offset of the fault current. With  $X/R = 10$  at 60 Hz the time constant  $T_a$  is 0.0265 s:

IEEE 80-2013, decrement factor

$$D_f = \sqrt{1 + \frac{T_a}{t_f}(1 - e^{-2t_f/T_a})} = \sqrt{1 + \frac{0.0265}{0.5}(1 - e^{-2(0.5)/0.0265})} = 1.026$$

IEEE 80-2013, maximum grid current

$$I_G = S_f D_f 3I_0 = 0.5(1.026)(5,000) = 2,565 \text{ A}$$

## 6.3. CONDUCTOR SIZE

The full fault current, with its decrement, can flow in a single grid conductor for the backup clearing time of 1 s. For annealed soft-drawn copper with exothermic joints, IEEE 80 Table 2 gives  $K_f = 7.00$ :

IEEE 80-2013, conductor sizing with Table 2 constant

$$A_{kcmil} = I K_f \sqrt{t_c} = 5.13(7.00)\sqrt{1.0} = 35.9 \text{ kcmil}$$

#2 AWG (66.4 kcmil) would carry the fault current. TORUS selected 4/0 AWG for the grid and loops because it resists mechanical damage during backfill, carries lightning current from the down conductors, and keeps the grid resistance and mesh voltages low; 2/0 and #2 AWG taps connect equipment to it.

The required conductor area is 36 kcmil. The 4/0 AWG grid (211.6 kcmil) and 2/0 AWG taps (133.1 kcmil) exceed it.

#### 6.4. TOLERABLE TOUCH AND STEP VOLTAGES

A thin, high-resistivity surface layer raises the voltage a person can tolerate. The reduction factor  $C_s$  for the 6 in pad aggregate ( $h_s = 0.1524$  m) is:

IEEE 80-2013, Eq. 27

$$C_s = 1 - \frac{0.09(1 - \rho/\rho_s)}{2h_s + 0.09} = 1 - \frac{0.09(1 - 15/1,000)}{2(0.1524) + 0.09} = 0.775$$

For a 50 kg person and a shock duration of 0.5 s:

IEEE 80-2013, Eq. 32 and Eq. 29

$$E_{touch50} = (1000 + 1.5 C_s \rho_s) \frac{0.116}{\sqrt{t_s}} = (1000 + 1.5(0.775)(1,000)) \frac{0.116}{\sqrt{0.5}} = 355 \text{ V}$$

$$E_{step50} = (1000 + 6 C_s \rho_s) \frac{0.116}{\sqrt{t_s}} = 927 \text{ V}$$

Table 6-2 gives the limits for each surface. Outside the fence the person stands on native soil, so  $C_s = 1$  and  $\rho_s$  equals the soil resistivity.

**Table 6-2: Tolerable Touch and Step Voltages, 50 kg, 0.5 s**

| Surface                         | $\rho_s$ , $\Omega\cdot\text{m}$ | $h_s$ , in | $C_s$ | Tolerable touch, V | Tolerable step, V |
|---------------------------------|----------------------------------|------------|-------|--------------------|-------------------|
| Pad aggregate (process area)    | 1,000                            | 6          | 0.775 | 355                | 927               |
| Crushed rock (electrical area)  | 3,000                            | 4          | 0.695 | 677                | 2,215             |
| Native soil (outside the fence) | 15                               | -          | 1.000 | 168                | 179               |

#### 6.5. GRID RESISTANCE AND GROUND POTENTIAL RISE

For the combined system the enclosed area is  $A = 4,899 \text{ m}^2$ , and the total buried length is  $L_T = 795.8$  m of conductor plus 49 rods of 3.048 m, or 945.2 m:

IEEE 80-2013, Eq. 52

$$R_g = \rho \left[ \frac{1}{L_T} + \frac{1}{\sqrt{20A}} \left( 1 + \frac{1}{1 + h\sqrt{20/A}} \right) \right] = 15 \left[ \frac{1}{945.2} + \frac{1}{\sqrt{20(4,899)}} \left( 1 + \frac{1}{1 + 0.610\sqrt{20/4,899}} \right) \right] = 0.110 \Omega$$

IEEE 80-2013, ground potential rise

$$GPR = I_G R_g = 2,565(0.110) = 282 \text{ V}$$

The numerical model, independent of Sverak's equation, gives  $R_g = 0.116 \Omega$ , which confirms the result. The electrical-area grid alone would have  $R_g = 0.411 \Omega$  and a ground potential rise of 1,056 V; that value is used below as an upper bound for the mesh check in the electrical area.

The station grounding system resistance is  $0.11 \Omega$  and the ground potential rise is  $282 \text{ V}$ . This is below the  $355 \text{ V}$  tolerable touch voltage on the pad aggregate, so no touch voltage inside the fence can exceed the limit whatever the mesh geometry.

## 6.6. MESH AND STEP VOLTAGES, ELECTRICAL AREA

The full grid current is assigned to the electrical-area grid alone. This ignores the current that the rest of the system carries away and so overstates the mesh voltage. Because the conductors are unevenly spaced, the spacing  $D$  is taken as the largest actual spacing,  $8.69 \text{ m}$ . With  $L_x = 23.47 \text{ m}$ ,  $L_y = 14.33 \text{ m}$ ,  $L_C = 179.8 \text{ m}$  and 12 perimeter rods:

IEEE 80-2013, geometric factor  $n$

$$n = n_a n_b = \frac{2L_C}{L_p} \sqrt{\frac{L_p}{4\sqrt{A}}} = (4.758)(1.015) = 4.83$$

IEEE 80-2013, Eq. 81

$$K_m = \frac{1}{2\pi} \left[ \ln \left( \frac{D^2}{16hd} + \frac{(D+2h)^2}{8Dd} - \frac{h}{4d} \right) + \frac{K_{ii}}{K_h} \ln \frac{8}{\pi(2n-1)} \right] = 0.882$$

with  $K_{ii} = 1$  (rods on the perimeter),  $K_h = \sqrt{1+h} = 1.269$ , and  $K_i = 0.644 + 0.148n = 1.359$ . The effective buried length is  $L_M = 241.5 \text{ m}$ :

IEEE 80-2013, Eq. 80

$$E_m = \frac{\rho K_m K_i I_G}{L_M} = \frac{15(0.882)(1.359)(2,565)}{241.5} = 191 \text{ V}$$

IEEE 80-2013, Eq. 92 and Eq. 94

$$E_s = \frac{\rho K_s K_i I_G}{0.75L_C + 0.85L_R} = \frac{15(0.327)(1.359)(2,565)}{166.0} = 103 \text{ V}$$

The numerical model gives a highest touch voltage of  $47 \text{ V}$  in the electrical area, well below the closed-form value, which confirms that the closed form is conservative here.

In the electrical area the mesh voltage is  $191 \text{ V}$  against a  $677 \text{ V}$  limit on crushed rock (and  $355 \text{ V}$  on the general aggregate), and the step voltage is  $103 \text{ V}$  against  $2,215 \text{ V}$ .

The mesh voltage would also pass on the general pad aggregate. TORUS nevertheless specifies clean crushed rock over the electrical area, because this is where people operate switchgear and the generator during a fault, and crushed rock roughly doubles the margin at small cost.

## 6.7. MESH AND STEP VOLTAGES, PROCESS AREA

The process area has coarse meshes up to 34.7 m across. The closed form, applied to the whole system with that spacing, gives  $E_m = 71$  V ( $n = 5.67$ ,  $K_m = 1.283$ ,  $K_i = 1.483$ ,  $L_M = 1033$  m) and  $E_s = 22$  V. The numerical model gives a higher touch voltage, 105 V, near the middle of the largest mesh at (65, 139), and a highest step voltage of 24 V. The larger values govern.

In the process area the governing touch voltage is 105 V against a 355 V limit, and the step voltage is 24 V against 927 V.

## 6.8. TOUCH VOLTAGE OUTSIDE THE FENCE

A person outside the fence stands on native soil, where the tolerable touch voltage is only 168 V. The perimeter loop lies 3 ft outside the fence, directly under where that person stands, and holds the surface potential there close to the grid potential. The numerical model gives a highest touch voltage of 114 V at 1 m outside the fence and a highest step voltage of 27 V. An isolated, separately grounded fence was considered and rejected: the fence passes within a few feet of XF-101 and B-102, so part of it would have to be bonded anyway, and the junction between bonded and isolated sections would need insulating fence panels that are easily bridged by maintenance.

Outside the fence the touch voltage is 114 V against a 168 V limit, and the step voltage is 27 V against 179 V.

## 6.9. NEC ARTICLE 250 REQUIREMENTS

The service is 480Y/277 V with 1/0 AWG copper service conductors (ELE-CAL-004). NEC Table 250.66 requires a #4 AWG copper grounding electrode conductor for that size; TORUS specifies 2/0 AWG from the service disconnect MCB-101 to the grid, sized to the lightning and fault duty of the grid rather than to the NEC minimum. The grounding electrode system is the grid with its ground rods, which meets NEC 250.52 and 250.53; the 25  $\Omega$  single-rod threshold of 250.53(A)(2) does not apply to a grid of 0.11  $\Omega$ . Equipment grounding conductors are sized to NEC Table 250.122 in ELE-CAL-004 and run in every power cable.

Standby generator G-101 is not a separately derived system. Transfer switch ATS-101 is three-pole with a solid neutral, so the neutral is bonded to ground only at MCB-101 (NEC 250.24(A)(5)); the generator neutral is not bonded to its frame. Dry-type transformer XF-102 is separately derived, and its neutral is bonded at the transformer with its grounding electrode conductor run to the B-102 main ground bus (NEC 250.30(A)). The utility bonds the XF-101 neutral and case to its own electrode and to the grid at the pad (HOLD H-10).

## 6.10. EQUIPMENT GROUNDING AND BONDING

Each item of equipment is connected to the grid as listed in Table 6-3. Vessels, skids and structures have two connections at opposite corners so that one broken tap does not leave them ungrounded. Valves and small items have one.

**Table 6-3: Equipment Grounding Connections**

| Item                 | Connection                                                                     | Conductor | Connections | Tap length, ft |
|----------------------|--------------------------------------------------------------------------------|-----------|-------------|----------------|
| PR-101               | Pig receiver barrel lugs                                                       | 2/0       | 2           | 20             |
| SDV-101              | Valve body / actuator bracket                                                  | #2        | 1           | 11             |
| V-101                | Filter separator saddle lugs                                                   | 2/0       | 2           | 18             |
| FG-101               | Fuel gas skid base, diagonal corners                                           | 2/0       | 2           | 52             |
| SK-110               | Meter skid base, diagonal corners                                              | 2/0       | 2           | 38             |
| SK-110 canopy        | Canopy columns (also lightning down conductors)                                | 2/0       | 8           | 150            |
| B-101                | Analyzer shelter ground bar and frame                                          | 2/0       | 2           | 34             |
| FCV-131/132 station  | Control valve station skid                                                     | 2/0       | 2           | 24             |
| SDV-102              | Valve / actuator                                                               | #2        | 1           | 11             |
| CKV-171              | Valve body                                                                     | #2        | 1           | 11             |
| SDV-103              | Valve / actuator                                                               | #2        | 1           | 11             |
| Pipe supports        | Pipe supports / sleepers, piping bond                                          | #2        | 5           | 81             |
| H-101                | Line heater skid, diagonal corners                                             | 2/0       | 2           | 66             |
| CP-150               | BMS panel stand                                                                | #2        | 1           | 27             |
| VS-101               | Vent stack base plate (two connections)                                        | 2/0       | 2           | 26             |
| T-101                | Tank shell lugs, opposite sides                                                | 2/0       | 2           | 36             |
| T-101 truck loadout  | Truck static grounding system (ground-verification monitor)                    | 2/0       | 1           | 19             |
| IJ-101, station side | Line 1001, station (east) side of IJ-101 only                                  | #2        | 1           | 16             |
| IJ-102, station side | Line 1041, station (south) side of IJ-102 only; riser and line 1042 not bonded | #2        | 1           | 21             |
| B-102                | Building frame and main ground bus                                             | 4/0       | 2           | 14             |
| MCB-101 service      | Service grounding electrode conductor to grid                                  | 2/0       | 1           | 6              |
| XF-101               | Transformer ground pad (utility neutral bond by utility)                       | 4/0       | 2           | 14             |
| G-101                | Generator frame / enclosure, diagonal corners                                  | 2/0       | 2           | 18             |

| Item                          | Connection                                        | Conductor | Connections | Tap length, ft |
|-------------------------------|---------------------------------------------------|-----------|-------------|----------------|
| ANT-201                       | Monopole base plate to mast ring, two connections | 2/0       | 2           | 14             |
| JB-W01                        | demarcation panel stand                           | #2        | 1           | 10             |
| Fence                         | Fence posts (corner, gate, line <= 50 ft)         | #2        | 23          | 181            |
| Lighting poles LP-P1 to LP-P8 | Pole base ground lug                              | #2        | 8           | 140            |

Note 1: Tap length includes 5 ft per connection for the riser and termination.

Piping is grounded through the equipment taps and the pipe-support bonds. Bolted flanges are electrically continuous for static purposes (API RP 2003) and are not jumpered, except across non-conductive gaskets or lined spools, where a #6 flexible jumper is installed. Every actuator, junction box, instrument stand and luminaire is also grounded by the equipment grounding conductor in its cable. T-101 has two connections to its shell, and the truck loadout has a self-testing static ground monitor that permits loading only when the truck is grounded (NFPA 77). Each gate leaf is bonded to its post with a flexible braid, and a 4/0 conductor is buried across each vehicle gate opening so that the gate area is inside the perimeter loop.

The ANT-201 antenna monopole is bonded at its base plate by two 2/0 conductors to its own 4/0 ring (X 146 to 154 ft, Y 18 to 26 ft) with four rods, and the ring is bonded to the process ring by two 2/0 conductors. The coaxial cable shields are bonded at the top of the mast, at its base and at the B-102 entry, where the buried coaxial cables terminate on arrestors bonded to the main ground bus.

## 6.11. INSULATING JOINTS

The station is electrically isolated from the upstream lateral by IJ-101 at (26.5, 8.0) and from the outlet lateral by IJ-102 at (220.0, 152.5). Only the station side of each joint is grounded: line 1001 east of IJ-101 and line 1041 south of IJ-102. The outlet riser at (220, 160) and the buried 12 in outlet lateral 12"-G-1042-A6 (108 ft) are on the lateral side, electrically continuous with the receiving pipeline operator's trunkline, and are not bonded to the station grounding system. Bonding them would short the joint, drain the trunkline's cathodic protection current into the station copper, and expose the station to the trunkline's fault and lightning currents.

No conductor, conduit, pipe support, handrail, tubing or cable tray may bridge either joint. Each joint is protected against lightning and fault overvoltage by a solid-state decoupler connected across it with leads shorter than 3 ft, rated per CP-CAL-001 and detailed on CP-DWG-002. The decoupler blocks the cathodic protection voltage but conducts fault and lightning current, so the joint cannot flash over. The arrangement at IJ-102 is subject to review by the receiving pipeline operator (HOLD H-01).

## 6.12. CROSSINGS OF BURIED PIPE

The grounding conductors cross buried pipe at the 7 points listed in Table 6-4. Copper in contact with coated steel would form a galvanic cell at any coating holiday and, on the outlet lateral, would connect the station copper to the trunkline's cathodic protection. At each crossing the copper passes at least 12 in from the pipe and is sleeved in 10 ft of Schedule 40 PVC centred on the pipe (AMPP SP0169).

**Table 6-4: Grounding Conductor Crossings of Buried Pipe**

| Line | NPS | Crossing at X, Y (ft) | Grounding conductor                          | Pipe side of insulating joint     |
|------|-----|-----------------------|----------------------------------------------|-----------------------------------|
| 1042 | 12  | 220, 203              | Perimeter loop (north)                       | Lateral (receiving operator's CP) |
| 1042 | 12  | 220, 168              | Process ring north, Y = 168                  | Lateral (receiving operator's CP) |
| 1051 | 2   | 130, 78               | Cross conductor N-S, X = 130                 | Station                           |
| 1051 | 2   | 216, 83               | Cross conductor in main cable trench, Y = 83 | Station                           |
| 1052 | 1   | 130, 46               | Cross conductor N-S, X = 130                 | Station                           |
| 1052 | 1   | 182, 34               | Electrical-area grid E-W, Y = 34             | Station                           |
| 1052 | 1   | 182, 44               | Electrical-area grid E-W, Y = 44             | Station                           |

## 6.13. SIGNAL REFERENCE GROUNDING AND SURGE PROTECTION

Instrument cable shields and the control system reference are grounded at one point, an isolated instrument reference bar in B-102 connected to the main ground bus by a single insulated 2/0 conductor (IEEE 1100). Shields are grounded at the B-102 end only, which keeps ground-potential differences during a fault from driving current through them. The 24 VDC system is ungrounded with ground-fault detection, and the 120 VAC UPS output is bonded at the UPS as a separately derived system.

Surge protective devices are provided at every point where energy can enter B-102 (NEC Article 242): a Type 1 device at MCB-101, Type 2 devices at DP-101, LP-101 and UP-101, coaxial arrestors on the antenna cables and a data-line protector on the RS-485 circuit to the receiving pipeline operator's demarcation panel.

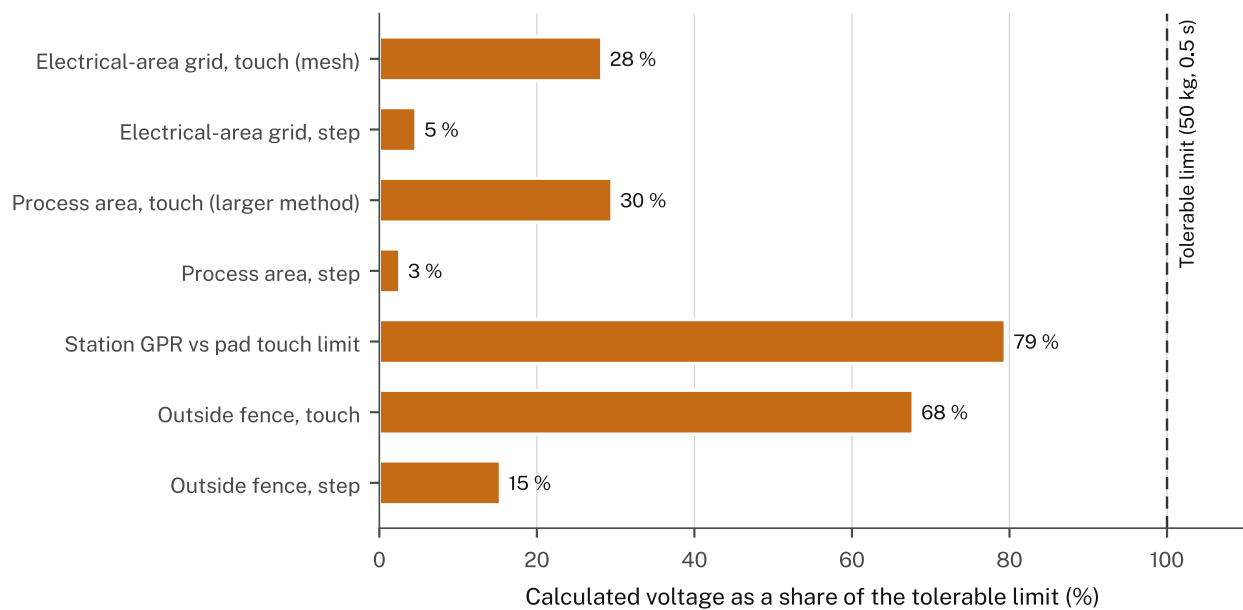
# 7. RESULTS AND CONCLUSIONS

Table 7-1 summarizes the checks. Figure 7-1 shows each calculated voltage as a share of its tolerable limit. The ground potential rise and the touch voltage outside the fence carry the least margin; both are driven by the assumed fault current and soil resistivity, which are the first values to confirm.

**Table 7-1: Grounding Check Summary**

| Check                            | Calculated        | Limit                        | Result |
|----------------------------------|-------------------|------------------------------|--------|
| Grid resistance, combined system | 0.11 $\Omega$     | 5 $\Omega$ target (IEEE 142) | Pass   |
| Ground potential rise            | 282 V             | 355 V (touch, pad)           | Pass   |
| Touch, electrical area           | 191 V             | 677 V                        | Pass   |
| Step, electrical area            | 103 V             | 2,215 V                      | Pass   |
| Touch, process area              | 105 V             | 355 V                        | Pass   |
| Step, process area               | 24 V              | 927 V                        | Pass   |
| Touch, 1 m outside fence         | 114 V             | 168 V                        | Pass   |
| Step, outside fence              | 27 V              | 179 V                        | Pass   |
| Conductor thermal size           | 36 kcmil required | 211.6 kcmil (4/0)            | Pass   |

**Figure 7-1. Calculated Touch and Step Voltages as a Share of the Tolerable Limits**



TORUS draws the following conclusions:

1. The grounding system shown in Appendix A limits touch and step voltages to within the IEEE 80 limits for a 50 kg person everywhere inside the fence and 1 m outside it, for the assumed 5 kA primary fault.
2. The combined system resistance of 0.11  $\Omega$  satisfies the IEEE 142 target and the NEC grounding electrode requirements. A fall-of-potential test of the completed system shall confirm a value of 1.0  $\Omega$  or less.
3. Clean crushed rock, 4 in deep, shall cover the electrical area from X 176 ft to the east fence and from the south fence to Y 44 ft, outside building slabs and pads.

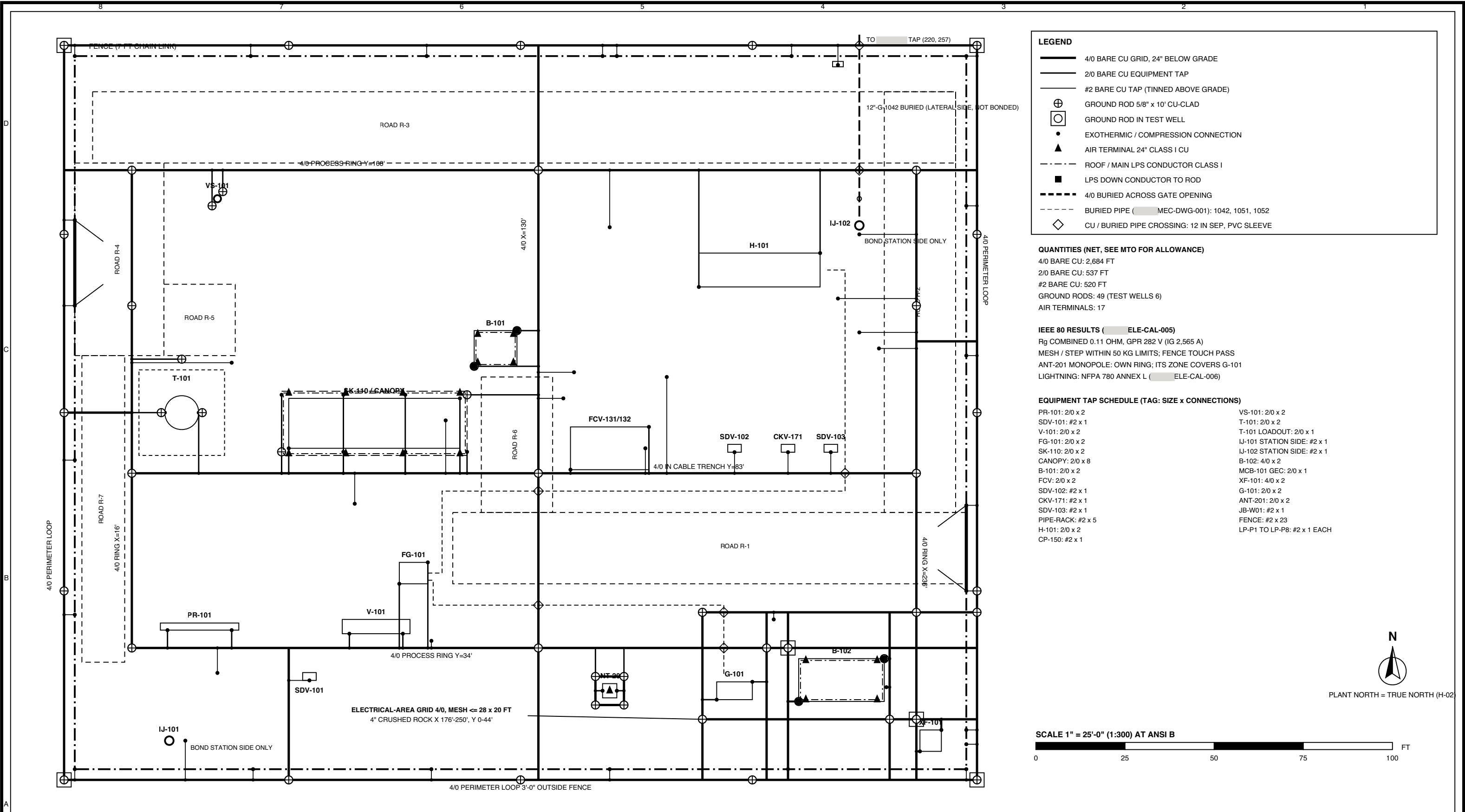
4. The fence shall be bonded to the perimeter loop at every corner, gate and line post at 50 ft or less.
5. Only the station side of IJ-101 and IJ-102 shall be grounded, and every grounding conductor crossing buried pipe shall be sleeved and separated as specified.
6. The calculation shall be re-run with the soil resistivity survey and the utility's fault data before the design is issued for construction.

The following items remain open: the soil resistivity survey (HOLD H-08), the utility fault current, X/R ratio and clearing time (HOLD H-10), the decoupler arrangement at IJ-102 (HOLD H-01), and a resistivity test of the pad aggregate.



## APPENDIX A. GROUNDING AND LIGHTNING PROTECTION PLAN





LEGEND

4/0 BARE CU GRID, 24" BELOW GRADE

2/0 BARE CU EQUIPMENT TAP

#2 BARE CU TAP (TINNED ABOVE GRADE)

GROUND ROD 5/8" x 10' CU-CLAD

GROUND ROD IN TEST WELL

EXOTHERMIC / COMPRESSION CONNECTION

AIR TERMINAL 24" CLASS I CU

ROOF / MAIN LPS CONDUCTOR CLASS I

LPS DOWN CONDUCTOR TO ROD

4/0 BURIED ACROSS GATE OPENING

BURIED PIPE (MEC-DWG-001): 1042, 1051, 1052

CU / BURIED PIPE CROSSING: 12 IN SEP, PVC SLEEVE

QUANTITIES (NET, SEE MTO FOR ALLOWANCE)

4/0 BARE CU: 2,684 FT

2/0 BARE CU: 537 FT

#2 BARE CU: 520 FT

GROUND RODS: 49 (TEST WELLS 6)

AIR TERMINALS: 17

IEEE 80 RESULTS (ELE-CAL-005)

Rg COMBINED 0.11 OHM, GPR 282 V (IG 2,565 A)

MESH / STEP WITHIN 50 KG LIMITS; FENCE TOUCH PASS

ANT-201 MONOPOLE: OWN RING; ITS ZONE COVERS G-101

LIGHTNING: NFPA 780 ANNEX L (ELE-CAL-006)

EQUIPMENT TAP SCHEDULE (TAG: SIZE x CONNECTIONS)

|                   |                             |
|-------------------|-----------------------------|
| PR-101: 2/0 x 2   | VS-101: 2/0 x 2             |
| SDV-101: #2 x 1   | T-101: 2/0 x 2              |
| V-101: 2/0 x 2    | T-101 LOADOUT: 2/0 x 1      |
| FG-101: 2/0 x 2   | IJ-101 STATION SIDE: #2 x 1 |
| SK-110: 2/0 x 2   | IJ-102 STATION SIDE: #2 x 1 |
| CANOPY: 2/0 x 8   | B-102: 4/0 x 2              |
| B-101: 2/0 x 2    | MCB-101 GEC: 2/0 x 1        |
| FCV: 2/0 x 2      | XF-101: 4/0 x 2             |
| SDV-102: #2 x 1   | G-101: 2/0 x 2              |
| CKV-171: #2 x 1   | ANT-201: 2/0 x 2            |
| SDV-103: #2 x 1   | JB-W01: #2 x 1              |
| PIPE-RACK: #2 x 5 | FENCE: #2 x 23              |
| H-101: 2/0 x 2    | LP-P1 TO LP-P8: #2 x 1 EACH |
| CP-150: #2 x 1    |                             |

SCALE 1" = 25'-0" (1:300) AT ANSI B

0255075100

FT

N

PLANT NORTH = TRUE NORTH (H-02)

NOTES / REFERENCES

1. GRID: BARE STRANDED CU 24 IN BELOW GRADE; BURIED JOINTS EXOTHERMIC (DWG-007).

2. FENCE POSTS (<= 50 FT) BONDED #2 TO LOOP; GATE LEAVES FLEXIBLE BRAID JUMPERS.

3. GROUND STATION SIDE OF IJ-101/102 ONLY; NOTHING MAY BRIDGE AN IJ (CP-DWG-002).

4. G-101 NOT SEPARATELY DERIVED; N-G BOND AT MCB-101 ONLY. XF-101 BY UTILITY.

5. T-101 LOADOUT STATIC GROUND MONITOR (NFPA 77). VS-101/T-101/H-101 SELF-PROT.

6. SOIL (H-08) AND FAULT DATA (H-10) ASSUMED. FALL-OF-POTENTIAL TEST <= 1.0 OHM.

REF: ELE-CAL-005, -CAL-006, -DWG-007; CP-DWG-001

REVISIONS

| REV | DATE       | DESCRIPTION             | BY | CHK | APP |
|-----|------------|-------------------------|----|-----|-----|
| A   | 2026-09-29 | ISSUED FOR REVIEW (IFR) |    |     |     |

PRELIMINARY - ISSUED FOR REVIEW - NOT FOR CONSTRUCTION

ENGINEER OF RECORD SEAL

NOT SEALED  
PRELIMINARY

PE NO. \_\_\_\_\_

PROJECT

120 MMSCFD RECEIPT INTO \_\_\_\_\_

\_\_\_\_\_  
COUNTY, \_\_\_\_\_

DISCIPLINE: ELECTRICAL

SCALE: 1" = 25'-0"

GROUNDING AND LIGHTNING PROTECTION PLAN

STATION GROUNDING SYSTEM

DRAWN: \_\_\_\_\_ CHECKED: \_\_\_\_\_ APPROVED: \_\_\_\_\_

DWG NO.

ELE-DWG-004

SHEET 1 OF 1 REV A