Title: **Substation Ground Grid Design Guide**	Standard No.: **SF0201 Rev.06**	Effective Date: **July 2022**
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1.0 INTRODUCTION

1.1 Purpose

The purpose of this design guide is to outline a standard method of designing substation ground grids for Entergy transmission and distribution substations.

1.2 Scope

This design guide should be used by the Entergy Substation Engineers in the design of substation buried ground grids based on safe limits of touch and step potentials, and to prevent damage to equipment & apparatus, including associated equipment such as communication cables during fault conditions. This guide does not discuss the following:

a) Measurement of soil resistivity

b) Grounding of the substation equipment, structures, and the type of conductor or grounding connectors

c) Substation shielding

d) Selection of grounding connectors

This guide covers the design of below ground component of the ground grid. Requirements for the installation of the ground grid, grounding of all above ground equipment, enclosures, bus structures and fences are specified in Entergy standard SF0202.

1.3 Changes for this revision

Updated language to require the ground grid be tested always in 6.0, added direction on evaluating the measured values and current ground grid design, removed duplicate lines in SF0201 A2 data table.

1.4 Effective Date

This Design Guide describes requirements as presently overseen by Substation Design, and is therefore effective immediately.

1.5 Training & Awareness Requirements

This Guide principally impacts substation design engineers. Substation Design Supervisors should assure that their design personnel are aware and follow its guidance.

2.0 DEFINITIONS, TERMINOLOGY

Ground Potential Rise (GPR): The maximum voltage that a station grounding grid may attain relative to a distant grounding point assumed to be at the potential of remote earth. This voltage, GPR, is equal to the maximum grid current times the grid resistance. ***(IEEE 80)***

Step Voltage: The difference in surface potential experienced by a person bridging a distance of 1 meter with his feet without contacting any other grounded object. ***(IEEE 80)***

Touch Voltage: The potential difference between the ground potential rise (GPR) of a ground grid and the surface potential at the point where the person is standing, while at the same time having his hands in contact with a grounded structure. ***(IEEE 80)***

Mesh Voltage: The maximum touch voltage to be found within a mesh of a ground grid. ***(IEEE 80)***

Transferred Voltage: A special case of the touch voltage where a voltage is transferred into or out of the substation from or to a remote point external to the substation site. ***(IEEE 80)***

3.0 REFERENCE STANDARDS & DOCUMENTS

3.1 ANSI C2, National Electrical Safety Code

3.2 IEEE Std. 80, Guide for Safety in AC Substation Grounding

3.3 IEEE Std. 81; Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System

3.4 IEEE Std. 367: Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage from a Power Fault

3.5 IEEE Std. 837: Standard for Qualifying Permanent Connections Used in Substation Grounding

3.6 Entergy AM-PD-SF01-001; Ground Grid Acceptance and Maintenance

3.7 Entergy TE-DB-FAC-001; Regulatrory Governance of Transmission Standards and Engineering Procedures

3.8 Entergy SF0202; Substation Grounding Specification

3.9 Entergy SL0003; Substation Design Guide

4.0 SAFETY

This guideline does not address all possible safety issues associated with its use. It is the responsibility of the designer to follow the safety advice and recommendations described in the industry standards and common utility practices, including Entergy's Operations/Customer Service Safety Manual, and federal, state, and local regulations.

The ground grid design must provide a safe environment that will assure that personnel in or in the vicinity of the substation facilities will not be exposed to the danger of critical electric shock caused by touch, step, and transferred potentials.

The ground grid design must ensure the proper operation of protective devices such as protective relaying and surge arresters.

The ground grid design must limit the level of transient voltages on equipment by providing a low impedance path for lightning discharges, switching surges, fault currents, and other system disturbances. These disturbances may otherwise cause extensive damage to equipment and apparatus, including associated equipment such as communication cables.

5.0 GROUND GRID DESIGN

5.1 Design Ground Fault Level

The first step in the design of substation ground grid is to establish a system fault level available and maximum expected fault current with fault duration at the site.

Entergy SL0003 provides guidance for the selection of design fault current levels for the substations. The selected fault current level shall be shown on the substation grounding plan drawing.

Existing substation ground grids should be reviewed and updated to comply with this standard as substation modifications are made. If fault current has increased since the ground grid was originnaly installed, the designer shall review grounding plan and provide specific scope for grounding in the vicinity of project work. For grounding recommendations outside of vicinity of project work, the designer shall review and determine whether to pass the information on to appropriate group internally or to incorporate it in the current project scope.

5.2 Design Process

Entergy ground grid design shall be based on IEEE std. 80. Computer Program WinIGS shall be used for detailed and complex ground grid analysis. For basic ground grid design of simple substation layouts a spreadsheet, available at \\Mobfsetsp004\TSG_Share\Transmission Stds\Ground Grid Design Spreadsheet.xls should be used.

The following field data, as applicable, per Attachment SF0201-A1, will need to be determined and/or collected for the ground grid design:

- **a)** Type of soil and soil resistivity
- **b)** Dimensions of area to be grounded
- **c)** System voltage(s) in substation
- **d)** Line to line voltage at worst fault location
- **e)** System fault level
- **f)** System X/R at fault location
- **g)** System growth factor
- **h)** Positive sequence equivalent system impedance
- **i)** Zero sequence equivalent system impedance
- **j)** Current division factor
- **k)** Fault duration
- **l)** Resistivity of crushed rock surfacing (wet)
- **m)** Depth of grid
- **n)** Thickness of crushed rock surfacing if the ground grid design depends upon the presence of crushed rock surfacing

The following steps should be used to design and construct substation ground grids:

- **I.** Check conductor size
- **II.** Determine tolerable touch and step voltages
- **III.** Design preliminary ground system
- **IV.** Estimate preliminary ground system resistance
- **V.** Determine maximum grid current
- **VI.** Calculate grid potential rise
- **VII.** Calculate mesh and step voltages
- **VIII.** Compare mesh voltage to tolerable touch voltage
- **IX.** Compare step voltage to tolerable step voltage
- **X.** Modify design as necessary
- **XI.** Finalize design
- **XII.** Construct ground system
- **XIII.** Obtain field measurements of the ground system resistance
- **XIV.** Review actual and calculated values of grid resistance
- **XV.** Modify ground system as necessary

5.3 Determination of Soil Resistivity

Soil resistivity is a large part of ground grid mesh spacing determination. In the absence of existing soil data in AM Meridian or soil boring database the designer shall arrange to have the soil resistivity measured in accordance with IEEE Std 81.

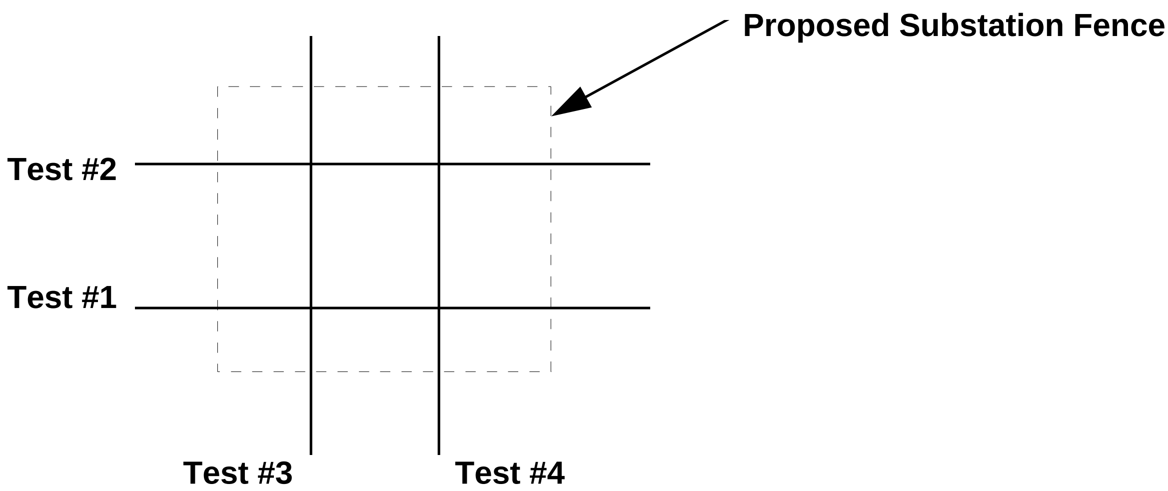
For green field new substation, the measurement should be conducted after site preparation work has been completed. The addition of fill dirt can alter resistivity measurements which makes the mesh spacing analysis invalid.

For existing substation, the measurements should not be conducted within the existing station or parallel to existing transmission lines. In energized substations a lethal voltage can exist between the ground system under test and the remote ground under normal conditions or if a ground fault occurs while tests are being conducted. Resistivity of soil in or near the existing substation will require testing samples of soil using a four terminal resistance measurement as described in IEEE Std 81.

When an existing substation is being expanded such that its grid area will be substantially inceased it can be assumed that the resistivity of the soil in the expansion area is same as that in the existing substation unless the soil structure is visibly different.

Soil resistivity measurements are made using four point probe location method as shown in Fig. 1.

Figure 1



5.4 Maximum Fault Current

In most cases, the ground fault current can be obtained from system fault studies, see 5.1 above. If the substation has a transmission line circuit breaker its rating should be compared with the maximum ground fault current to verify that the circuit breaker rating is adequate.

Both WinIGS and the spreadsheet calculate the ground fault current including DC offset. When using the spreadsheet it will be necessary to apply current split factor to account for current division between the ground grid and the alternate paths to the source. These return paths include overhead shield wires and feeder neutrals. Consult appropriate curve from Annex C of IEEE Std. 80 for the values of the split factor for input in the spreadsheet.

The maximum fault current shall be determined as follows:

The maximum grid current, I_G, is the value of ground fault current that flows through the substation-grounding grid into the earth. This current can be expressed by:

$$I_G \quad I_f \quad S_f \quad D_f \quad C_p$$

where;

I_G maximum grid current, amps

I_f symmetrical RMS ground fault current, amps

S_f current division factor

D_f decrement factor

C_p growth factor

The following procedures should be followed to obtain the equation parameters

5.4.1 Distribution Substations

For distribution substations with the transformer grounded only on the distribution side, the worst fault location for $\mathbf{I_G}$ is the high side terminals of the transformer.

For faults on the low side terminals and bus of a secondary grounded transformer, the transformer's contribution to the fault circulates in the station grid and there will be negligible GPR so this case does not have to be considered.

For Faults on the distribution system, one or two spans out, the GPR is generally significantly less than a high side induced GPR. The reason for this would be the total fault current flowing through the feeder phase conductor induces a large portion of the current to flow back to the substation via the neutral conductor and just circulate. The engineer must verify that all distribution and transformer neutrals are in good condition and are solidly attached to the grid. For faults far enough away to see the full resistance of the grounding system, GPR would be even less of a problem because the fault magnitude would be significantly less due to the additional feeder impedance. Thus, a fault on the distribution side of a typical substation transformer rarely results in the worst case determining the maximum grid current.

5.4.2. Transmission Substations

In Transmission Substations with three winding transformers or autotransformers, the worst fault for $\mathbf{I_G}$ may occur on either the high or low side of the transformer. Both locations should be checked. In either case, it can be assumed that the worst fault location is at the terminals of the transformer inside the substation, if the system contribution to the fault current is larger than that of the transformers in the substation. If the transformer contribution dominates, the worst fault location contributing to GPR may be outside the substation on a transmission line.

5.4.3 Apply Decrement Factor, $\mathbf{D_f}$,

The decrement factor, $\mathbf{D_f}$, is used to obtain an RMS equivalent of the asymmetrical current for a given fault duration. The ground fault current obtained from fault studies is a RMS symmetrical fault current. The decrement factor will be applied to account for the effect of the DC offset. Using the Table "2" below, and knowing the total clearing time of a fault at the substation under investigation, the typical values for the decrement factor can be determined.

To be totally correct, the decrement factor should be included in the selection of the worst fault location and the current split factor $\mathbf{S_f}$**.** However, for practical applications, the maximum RMS symmetrical grid current $\mathbf{(I_f * S_f)}$ is determined without regard to $\mathbf{D_f}$. Then, $\mathbf{D_f}$ is determined for the worst fault location. Thus $\mathbf{I_f * S_f * D_f}$ gives the equivalent RMS asymmetrical fault current flowing between the grounding system and surrounding earth.

TABLE "2"

Decrement Factor D_f					
FAULT DURATION t_f (sec)	**Cycles**	**D_f X/R =10**	**D_f X/R =20**	**D_f X/R =30**	**D_f X/R =40**
.00833	0.5	1.576	1.648	1.675	1.688
.05	3	1.232	1.378	1.462	1.515
.10	6	1.125	1.232	1.316	1.378
.20	12	1.064	1.125	1.181	1.232
.30	18	1.043	1.085	1.125	1.163
.40	24	1.033	1.064	1.095	1.125
.50	30	1.026	1.052	1.077	1.101
.75	45	1.018	1.035	1.052	1.068
1.00	60	1.013	1.026	1.039	1.052

5.4.4 Apply Growth Factor. C_p

Future changes to the power system or at the substation being designed may result in increased values of grid current, decreased values of grid current, or may result in no change at all for the grid system being designed. When transmission line side fault current is used for grounding calculations, the potential growth should be analyzed based on the 10-year forecast to calculate the appropriate growth factor. Transmission Planning should be consulted for this data. In the absence of specific fault level data a growth factor of 1.25 should be applied to the current fault level.

5.5 Ground Conductor Sizing

The size of the ground conductor depends on the maximum fault current as calculated in 5.4 above, fault duration, and conductor temperature limits.

The fusing current for ground grid conductors should be calculated using equations and material constraints given in IEEE Std. 80.

Unless the calculations show otherwise the current Entergy practice is to use minimum size of 4/0 soft drawn 7 strand copper grid conductors. For higher current values either 250 MCM copper or 2 X 4/0 copper may be used.

As an alternative to 4/0 copper conductor, with prior Entergy approval, 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity may be used as grid conductor.

If hard drawn copper conductor is used for mechanical or other reasons then its temperature rise shall be limited to 250 ^{0}C to prevent annealing.

5.6 Ground Grid Design and Layout

Typically this requires creating a basic ground grid layout superimposed on the substation overall plan view and foundation plan drawings. This basic ground grid layout consists of the following:

a) A continuous cable loop laid three feet outside the proposed substation fence line to enclose as much area as practical. Enclosing more area also reduces the resistance of the ground grid. This loop should enclose the fully open position of the outward opening swing gates. Also see 7.2 below.

b) Within the loop, a grid is created by cables laid in parallel lines in a grid pattern typically spaced 10 ft. to 40 ft. and, where practical, along the structures or rows of equipment, to provide for short ground connections. Large soil resistivity values will require closer mesh spacing.

c) The grid cables shall be buried at a nominal depth of 24 inches below finished grade (prior to the installation of a crushed rock layer if required). At cross-connections, the cables shall be securely bonded together.

d) Ground rods should be added at the grid corners and at each second junction point along the perimeter. Ground rods should be installed at major equipment. In multi-layer or very resistive soils, it might be necessary to use longer rods.

e) The ratio of the sides of the mesh usually is from 1:1 to 1:3 unless a precise (computer-aided) analysis warrants more extreme values.

Once the ground grid is designed, ground leads are provided from the ground grid to all above ground equipment. For grounding of equipment, refer to Entergy Standard SF0202. Ensure that the equipment grounding method complies with the requirement of the equipment manufacturer. The Entergy standard grounding details drawing should also be referenced on the grounding plan

The grounding plan should also include a Bill of Materials table including the description of the material, quantity and stock code number for each piece of material.

The grounding plan shall include a table illustrating the input and results of the grounding analysis, such that the analysis could be repeated with accuracy. The data table is illustrated in Attachment SF0201-A2.

5.7 Using WinIGS

The program WinIGS will be used to perform analysis and design of a grounding system. It will allow the designer to model the power system with the grounding system. Soil resistivity is obtained from tests done at site, and design short circuit value is obtained from CAPE. The data is then input into the WINIGS. Using trial and error the ground grid conductor spacing and number and depth of the ground rods is refined to a value where the maximum step and touch ground potential rise is within the Entergy allowable limits. WinIGS provides other data to complete the ground grid design.

5.8 Using Spreadsheet

In general the method of ground grid design is similar to that for using the WinIGS except that it requires separate steps and inputs to each step to determine the grid requirements.

5.9 Tolerable Step and Touch Voltages

Tolerable touch and step potentials should be calculated for a 50 kg body using surface material resistivity shown in Table 1, and fast fault clearing times for transmission and slow fault clearing time for distribution substations. The surface layer material and thickness selected to calculate the touch and step potentials shall be noted on the Attachment SF0201-A1 and substation grounding plan drawing. The thickness selected should be such that its insulation property will not get impaired through filling of the voids by compression and settlement of airborne dust.

Entergy typically applies a minimum of six inches of compacted crushed stone (#610, class 7 base, DGA or equivalent) and compacted to a minimum density equal to 95% of the maximum density obtained by a Modified Proctor Test (ASTM D-1557). Six inch depth of the crushed rock is recommended from a practical point of view to account for settling and filling of the voids by compression and dust. However the grid design calculations should be based upon a base from zero to six inches.

Resistivity of surface material selected for application shall be verified by tests.

TABLE 1
TYPICAL RESISTIVITIES OF SURFACE MATERIALS USED IN SUBSTATIONS

NO.	DESCRIPTION OF SURFACE MATERIAL	DRY - m	WET - m
1	Crusher Run Granite with Fines	$140x10^6$	1,300
2	#57 Washed Granite Similar to 3/4 in Gravel	$190x10^6$	8,000
3	Clean Limestone Slightly Coarser than Number 2	$7x10^6$	2,000-3,000
4	Washed Granite Similar to 3/4 in Gravel	$2x10^6$	10,000
5	Washed Granite Similar to pea Gravel	$40x10^6$	5,000
6	Crushed Aggregate Base Granite (with fines)	---------	500-1,000
7	Concrete	$1X10^6$ to $1X10^9$	21-100
8	Asphalt	$2x10^6$ to $30x10^6$	10,000 to $6X10^6$

Case 1: *Primary relaying fault-clearing times, with all lines in

System Voltage (kV)	Clearing Time cycles(seconds)
500	3.5 (0.0583)
345	3.5 (0.0583)
230	4.5 (0.075)
161	12 (0.2)
138	12 (0.2)
115	12 (0.2)

In all cases, if instantaneous reclosing is used, the initial clearing time must be multiplied by two.

Case 2: Backup relaying, local breaker failure
In substations with an n-1 breaker scheme, assume a transmission line side fault with local breaker failure. Use 20 cycles for clearing time and assume fault on weakest source to allow maximum fault current flow into fault. In Substations with one circuit breaker per line, assume a bus fault that initiates local breaker failure on the strongest source. Use 20 cycles for clearing time. In substations where there are no local transmission breakers, assume breaker failure at strongest end.

5.10 Ground Grid Resistance

Proper protective device operation depends on a relatively low value of substation ground grid resistance to the surrounding earth. An acceptable value of ground grid resistance is less than one ohm. If value less than 1 ohm is not obtainable through ground grid modifications, it may be necessary to use chemical treatments of the soil, install drilled ground wells, or divert fault current.

5.11 Maximum Grid Potential Rise

Maximum grid potential rise is the potential to which the grid will be elevated during periods of maximum ground grid current flow. Maximum grid potential rise is important when dealing with transferred potentials. Transferred potentials are the result of metal objects that provide an uninterrupted path outside the substation, being bonded to the substation's ground grid. This in effect transfers the potential of the ground grid to locations remote from the substation where potential gradient control is not provided. The result of this condition is that a person touching this metal object and standing on the earth at some point remote from the substation where the earth potential is essentially zero would encounter a potential difference equal to the maximum grid potential rise. Therefore, if the maximum grid potential rise exceeds the maximum allowable mesh voltage, precautions must be taken to place insulating links when required in all metal objects extending beyond the substation fence. The major danger area for transferred potential is communication links, perimeter fences, pipes, shield wires, and low voltage neutral wires tied to the links.

6.0 FIELD MEASUREMENT OF GROUND GRID RESISTANCE

After the ground grid has been installed, the resistance of the grid shall be measured using one of the test methods and techniques used in IEEE 81. The measurement shall be compared with the calculated values to validate the current ground grid design. If the field measured values are lower than the calculated values used in the ground grid design, the design shall be re-evaluated with the measured values to ensure no further modifications are required to be within the tolerable step and touch potentials. The field measurements shall be documented on the grounding plan in the data table shown in SF0201-A2 and the data table shall be updated per iteration of ground grid design analysis with field measured values.

Entergy AM-PD-SF01-001 describes a procedure to perform acceptance testing of new ground grids and performing diagnostic tests on existing ground grids.

7.0 FENCES

7.1 Fence Grounding

Fences pose an especially tough problem since they are accessible to the general public. The possibilities for fences involve tying the fence to the station ground grid, isolating the fence from the grid, or placing horizontal ground wires for gradient control inside, under, or outside the fence. Each possibility has strong and weak points which must be taken into account at the individual installations.

The substation grounding design should be such that the touch potential on the fence is within the calculated tolerable limit. There are two different methods that are acceptable for grounding the substation fence:

- **a)** Include the fence within the substation ground grid area with an electrical bond to the main grid.
- **b)** Locate the fence outside of the substation ground grid area with no electric bond to the main grid. This is not a recommended practice.

The first method is preferred because it will generally increase the size of the ground grid. This will thereby decrease the total resistance of the grid.

If the fence has to be located outside the substation ground grid, the following factors must be considered:

- **a)** Accidental energizing through a fallen conductor.
- **b)** Induced potentials during other types of faults (coupling through the soil).
- **c)** Can complete metallic isolation of the fence and substation ground grid be assured at all times.

These dangers can be reduced if the fence is tightly bonded to its own grounding system, i.e., loop conductor and ground rods.

7.2 Location of perimeter ground

All substations shall contain a perimeter ground located preferrably 3 feet on the outside of the substation fence. This perimeter ground should enclose outward opening swing fence gates. If installation of perimeter ground 3 feet outside the fence is not possible, the perimeter ground should be located at the fence line. In this case, the touch potentials present 3 feet on the outside of the fence shall be calculated to determine if the potentials are within tolerable limits. For these cases where the cable cannot be laid outside the fence line it may also be necessary to install inward opening swing or sliding fence gates. For these installations the swinging fence gate shall be prevented from swinging outwards.

7.3 Privately Owned or Perimeter Fences

Substation fences should not approach closer than 10 feet to any metallic component of a privately owned fence. In cases of good soil coupling, up to 80% of ground potential rise (GPR) can be transferred to the metallic portion of the privately-owned fence. Note that

Entergy standard isolation fence section is six feet wide, two such sections would be required. In cases where a privately owned or perimeter fence is closer than 10 feet, the program **WinIGS** must be used to properly evaluate transferred potential.

7.4 Service Areas

Many times the initial design of the substation is such that it will have a much larger area that will be fenced but the substation utilized area itself is much smaller and the ground grid is designed and constructed only in the small utilized area and along the substation fence. The remaining area will be unprotected area within the fenced area. This area is often used as storing or general service area. The ground grid design should verify that step and touch voltages in this unprotected area are within limits.

This service area may be separated from the utilized area by a separate ungrounded fence. A non-conducting fence may also be considered.

8.0 SWITCH OPERATING HANDLES

8.1 Other special problem areas besides transferred potentials are operating handles for switches and the substation protective fence. The substation grid should adequately protect operating handles inside the substation. A ground mat is not necessary underneath the operating handle.

8.2 Potential gradient control within the substation should preclude a person encountering lethal potential differences. However, painful body current flow can be encountered and for this reason operating personnel should use properly inspected and tested rubber gloves when operating switches or other devices within energized substations.

9.0 NOT USED

10.0 NOT USED

11.0 RESPONSIBILITIES

The Managers and Supervisors of Design are responsible for assuring that all facilities are designed and constructed in accordance with standards.

11.1 Interpretation

Interpretation of this standard is the responsibility of the Design Managers and Design Supervisors. Questions should be directed to Transmission Design Basis.

11.2 Deviation

Deviations from this Standards may be made only with the consent of Manager of Substation Design or an approved agent thereof.. Any deviation shall be reported to the Manager of Transmission Design Basis for consideration of inclusion in the standard. Deviations for any specific project should be documented through the appropriate change management process. No other employee has authority to grant deviations.

11.3 Regulatory Requirements

This document contains activities addressing FERC/NERC compliance commitments. Document preparers shall review document number TE-DB- FAC-001 to verify that revisions to this document do not reduce compliance with the regulatory commitments.

12.0 ACKNOWLEDGEMENTS

Marnie Roussel for extensive review and suggestions for improvement. Julie Wilcox and Diego Ortiz also contributed with helpful comments and suggestions.

13.0 ATTACHMENTS

13.1 SF0201-A1: Design Input Data
13.2: SF0201-A2: Grounding Plan Data Table

The following data shall be collected prior to the ground design.

	Substation name	
	Highest Voltage in substation	
	Positive sequence equivalent system impedance (Z_1)	
	Zero sequence equivalent system impedance (Z_0)	
	System fault current level, three phase (present)	
	System fault current level three phase (ultimate)	
	System growth factor	
	Current split factor (S_f)	
	Maximum grid current (rms)	
	Fault duration	
	Voltage at worst-fault location	
	System X/R ratio at fault	
	Substation grounding area (Length X Width)	
	Upper Soil resistivity (measured)	
	Upper Soil thickness	
	Lower soil resistivity (measured)	
	Type of surfacing material (e.g. crushed rock)	
	Surfacing material resistivity	
	Thickness of surfacing material (min 6 inches)	
	Depth of grid burial	
	Type of grid conductor	
	Size of grid conductor	
	Number of ground rods	
	Length of each ground rod	
	Diameter of ground rod	
	Number of parallel grid conductors in "X" plane	
	Maximum length of each parallel conductor	
	Number of parallel grid conductors in "Y" plane	
	Maximum length of each parallel conductor	
	Ground grid resistance (calculated)	
	Ground grid voltage rise (GPR)	
	Touch voltage (calculated)	
	Touch voltage (tolerable for 110 lbs. body weight)	
	Step voltage (calculated)	
	Step voltage (tolerable for 110 lbs. body weight)	

The following data table shall be shown on the Substation Ground Plan.

	Tool used to model Fault Current, including month & Year	
	Single Phase Fault Current (Symmetrical)	
	X / R Ratio	
	Three Phase Fault Current (Symmetrical)	
	X / R Ratio	

Grounding Analysis		
	Tool used for Analysis including year (eg WINIGS)	
	Upper Layer Soil Resistivity (measured)	
	Upper Layer Soil Thickness	
	Lower Layer Soil Resistivity (measured)	
	Lower Layer Soil Thickness	
	Surfacing Material eg Crushed Rock Resistivity	
	Surfacing Material eg Crushed Rock Thickness (inches)	
	Current Split Factor (WINIGS), %	
	Total Fault Current (rms), kA	
	Voltage Rise of Grid to Remote Earth (GPR), kV	
	Ground Grid Resistance (ohms)	
	Expected Earth Return Fault Current (rms)	
	Electric Shock Duration (sec)	
	NOTE: GPR Study Based on 1.25 times Three Phase Fault Current (Assumed for Future Growth)	

	For a 110 Lbs Person	
	Tolerable E Touch Voltage (volts)	775.8 Volts
	Calculated E Touch Voltage (volts)	
	Tolerable E Step Voltage (volts)	2510.1 Volts
	Calculated E Step Voltage (volts)	

	Field measured value of the substation ground grid GPR	
	Field measured value of the substation ground grid resistance	

Entergy

ENTERGY TRANSMISSION STANDARDS
SUBSTATIONS
CONSTRUCTION SPECIFICATION

Title: Substation Grounding Specification	**No. & Rev:** SF0202 R06	**Effective:** Nov 2019
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Rev. No	Revised Sections	Date	Rev. by	App. by
1	Title, Section 3.6.1	May 2001		
2	Reformatted, sections rearranged and renumbered, Scope includes 500 kV	Aug 2005	DS	MB
3	Added 1.3, and 11.3. Added copper clad steel as an alternative to copper conductor.	Nov 2007	DS	MB
4	Changed depth of grid to 24” in 4.4.1.	June 2008	DS	MB
5	Major revision, standard converted to a construction specification	Jan 2013	DS	MB
6	(See 1.3) Sections revised 2.0, 3.0, 5.6, 7.0, 8.0, 10.2, 10.4	Nov 2019	DS	KB

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1.0 INTRODUCTION

1.1 Purpose

The purpose of this Specification is to establish uniform installation practices with respect to construction of the station grounding system in substations.

1.2 Scope

This Specification clarifies the requirements for the installation of substation ground grids, grounding of substation equipment enclosures, bus structures, types of conductors, connectors, materials and method of their installation in substations 500 kV and below. The design of a ground grid, including calculations, is described in SF0201. This Specification applies to new substations, and wherever possible, modifications of existing stations.

1.3 Changes for this revision

Added definitions in 2.0, references updated in 3.0, added threaded ground rods and coupling in 5.6, added grounding of swing and sliding gated in 7.0, added grounding and method of grounding steel grating in oil containment pits in 8.0, clarified termination of distribution circuit neutrals in 10.2, added section 10.4 for grounding of transmission/distribution dead-end structures outside the substation. Clarified drawing references. There were several editorial type changes.

1.4 Effective Date

This Specification substantiates present requirements and is therefore effective immediately.

1.5 Training & Awareness Requirements

This Specification principally impacts technical personnel in Substation Design and Construction. Supervisors and Managers of Substation Design and Construction should assure that their personnel are aware and follow its guidance.

2.0 DEFINITIONS

Finished Grade: Design site elevation, after site grading.

Final Grade: Site elevation, after addition of a layer of crushed rock, usually 6” thick, to the finished grade.

3.0 REFERENCE STANDARDS & DOCUMENTS

3.1 IEEE Std. 80- Guide for Safety in AC Substation Grounding.
3.2 IEEE Std. 837, Standard for Qualifying Permanent Connections Used in Substation Grounding.
3.3 Entergy SF0201, Substation Ground Grid Design Guide.
3.4 Entergy SF0401, Substation Shielding Design Guideline
3.5 Entergy SL0205, Conduits and Duct Banks Construction Guide
3.6 Entergy SMGR01A0; Substation Standard Grounding Drawing Details 1 – 10
3.7 Entergy SMGR02A0; Substation Standard Grounding Drawing Details 11 – 15
3.8 Entergy SMGR03A0; Substation Standard Drawing Switch Structure Grounding
3.9 Entergy AL1201, General Contractor Requirements for Major Substation Construction
3.10 Entergy AL1203, Standard Requirements – Substation Purchase Specification
3.11 Entergy SL0001, Substation Design Parameters
3.12 Entergy SL0003, Entergy Substation Design Guide
3.13 Entergy SL1201, Ground Covering and Access Road Design Guidelines
3.14 Entergy Transmission & Utility Operations Safety Manual

4.0 SAFETY AND ENVIRONMENT

All Entergy safety rules apply. Refer to Entergy’s Transmission & Distribution Safety Manual for safety guidance and details. Also see Entergy AL1201 for safety related requirements applicable to contractors.

5.0 GROUND GRID

5.1 General

The substation ground grid conductor type and size, grid conductor spacing, number, length and locations of ground rods, need for crushed rock topping etc. is determined by calculations described in Entergy SF0201. This information is shown on the substation grounding plan and is supplemented with standard grounding detail drawings SMGR01A0, SMGR02A0 and SMGR03A0. The substation grounding plan will also show if addition of bentonite or an approved Ground Enhancement Material, or any other chemical soil treatment is required. The installation of bentonite and Ground Enhancement Material shall be per manufacturer's instructions.

All Grounding connections and other required grounding work shall be installed in accordance with the requirements of the applicable Substation Grounding Plan. No changes shall be made to these installation requirements without the prior approval of the Substation Designer.

5.2 Ground Grid Conductors

All below ground conductors shall be bare soft drawn copper. Unless Substation Design requirements dictate larger conductors, the grid below ground shall consist of a series of crossing parallel 4/0 AWG, 7 strand concentric (bare soft drawn) copper conductors uniformly spaced and exothermically welded together at every cross-connection. In general, ground grid conductor runs should be placed no closer than 2 feet from foundations. This is a practical limitation for most digging equipment.

Above ground "pigtails" and ground conductor run in prefabricated cable trenches in the station yard shall be 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity, unless design dictates larger or parallel conductors.

5.3 Connections

5.3.1 All connectors shall comply with the requirements of IEEE Std 837.

5.3.2 All below ground connections shall be exothermic weld and as specified for the project. Typically, these are Type PT (or PTC) connections; however, connector Type XB (or XBC) is an acceptable alternate for cross connections, and Type TA (or TAC) is an acceptable alternate for tee connections. See Entergy Drawing SMGR01A0.

5.3.3 All exothermic connections shall be made in accordance with the manufacturer's recommended practices and procedures.

5.3.4 When making exothermic welds to galvanized surfaces, wire brush the galvanized finish until bright metal shows, weld, then treat the immediate area with galvanox or other zinc rich preparation.

5.3.5 Bolted or compression connections are suitable for above ground connections, except for gate grounding.

5.3.6 All above grade ground connections to equipment shall be 2-hole ground lugs, bolted or compression

5.3.7 Bolted grounding connections involving aluminum to copper connection shall incorporate a suitable tin-plated connector or an approved bi-metallic transition plate. Electrical Joint Compound shall be used in aluminum-copper connections.

5.3.8 Bolted grounding connections should be treated with General Purpose Electrical Joint Compound applied in a manner so as not to spill over onto bolt threads thus affecting bolt torque values.

5.4 Grid Conductors Buried Depth

5.4.1 Ground grid conductors shall be installed at a nominal depth of twenty four (24) inches below finished grade (prior to the installation of a crushed rock layer if required).

5.4.2 Trenches shall be located as shown on the ground plan. Where machine trenching is near existing concrete foundations, care shall be taken not to damage concrete foundations. Hand trenching may be necessary in some locations. Ground wires shall be placed within a tolerance of ± six (6) inches from any established references. Trenching depths shall be within a tolerance of plus six inches or minus three inches. Bentonite shall be added if specified on the project ground plan.

5.5 Substation Surface Material

5.5.1 When required to meet design criteria and reduce surface voltage gradients, a layer of crushed stone shall be placed on top of finished grade. This layer shall be a minimum of six inches of crushed stone (#610, class 7 base, DGA equivalent) and compacted to a minimum density equal to 95% of the maximum density obtained by a Modified Proctor Test (ASTM D-1557). The crushed stone shall be placed a minimum of five feet to a maximum of ten feet outside the fence. Where the property line is closer than five feet outside the fence, the crushed rock shall stop at the property line. This surface treatment is designed to provide a high resistance surface layer with a resistivity approaching 3000 ohm-meters. See Entergy Drawing SMGR01A0.

5.5.2 Crushed stone installed to meet design criteria should be installed after all foundation, fence and trenching work are complete to protect the integrity of the high resistance surface rock layer. Crews working in a substation yard which incorporates crushed stone as part of the ground system design should take precautions to maintain the electrical characteristics of the surface crushed stone and prevent mixing this high resistance surface with station soil.

5.5.3 The resistivity of wet concrete is very low (20-100 ohm-meters) as compared to the crushed rock and special care should be used if concrete walkways or pads are used within the substation. In cases where crushed rock is needed to reduce ground potentials below tolerable levels, a perimeter ground conductor should be looped around the concrete walkway or pad. If asphalt is used, no special procedures are required.

5.6 Ground Rods

The principal function of ground rods is to make good contact with the earth. The ground rods should penetrate below upper level soils that are subject to variations in soil resistivity due to temperature and moisture content. Ground rods are very useful in dissipating high frequency transients directly to deeper soils that have lower resistivity. The following are guidelines for selecting, placing and connecting ground rods to a station ground grid, located where conditions are normal:

a) Driven rods should be constructed of 13 Mil copper-clad steel.

b) Ground rods shall preferably be non-threaded, 5/8" diameter, 10 feet Sectional. Threaded rods are also acceptable.

c) Ground rods shall be connected to the station grid conductor using the exothermic type GT 4/0 AWG conductor to 5/8" ground rod connection.

d) When necessary, threaded ground rods shall be connected together using a threaded coupler and driven to greater depths. Compression type couplers shall be used for non-threaded rods.

e) Grounding rods shall have a minimum spacing of 10' to reduce the proximity effect.

f) Ground rods should be located at each second junction point along the perimeter of the grid.

g) Ground rods should be located near surge arresters, rod gaps, and shield wires for incoming lines, transformers, and lightning masts.

h) Ground rods shall be installed in all fence corner areas of new installations. The ground rods shall be installed in conjunction with half interval or cross connections designed to lower surface gradients at corners. See Entergy Drawing SMGR01A0.

i) Ground rods shall be installed utilizing Entergy approved ground rod drivers. It should be ensured that the ground rod ends are not disfigured during installation and allow proper rod coupling with compression or threaded couplings as applicable.

j) Ground enhancement material shall be applied when specified on the substation ground plan.

6.0 SUBSTATION EQUIPMENT GROUNDING

6.1 Substation Transformers

6.1.1 A transformer ground loop shall be installed underground around the perimeter of the transformer concrete foundation with ground rods at all four corners and connected to the main ground grid at all four sides. Perimeter ground grid conductor shall be no closer than twenty four (24) inches from foundation and twenty four (24) below finished grade (prior to the installation of a crushed rock layer). Depth of driven ground rods is to be determined for each location. See Entergy Drawing SMGR02A0.

6.1.2 Power transformer neutrals (typically H_o and X_o bushings) when required to be grounded shall be connected to the transformer ground loop by its own separate path (copper bus bar or copper clad steel conductor) independent of the transformer case or other grounds. The neutral grounding conductor shall be at least the equivalent of two 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductors with 40% conductivity in parallel. This is required to conduct the available fault current to ground. All copper ground bars shall be painted ANSI 70 gray.

6.1.3 Power transformer tanks shall be grounded independently at a minimum of two diagonally opposite corners.

6.1.4 Autotransformers and regulators shall be bonded at a minimum of two (2) separate locations, which shall be at diagonally opposite corners.

6.1.5 Terminal of the tertiary winding of three phase auto transformers shall be grounded. When the auto transformer has all terminal of the tertiary winding brought out, and the tertiary is not intended to be connected to an external load, one of these terminals shall be grounded. For single phase auto transformers, the tertiary winding terminals of each auto transformer shall be externally connected in delta, and one terminal of the delta shall be grounded. The tertiary grounding conductor shall be one 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity.

6.1.6 All above grade ground connections to transformer shall be 2-hole ground lugs, bolted or compression. All below grade connections shall be as specified in section 5.3.2 above. See Entergy Drawing SMGR01A0.

6.2 Instrument Transformers

Voltage transformers (VTs), current transformers (CTs) and CCPD's cases shall be grounded and connected to the substation ground grid by a ground conductor. The supporting structure shall not be used as a grounding path.

6.3 Circuit Breakers and Switchgear

6.3.1 Circuit breakers shall be grounded on opposite corners of the breaker, with a minimum of two grounds per breaker.

6.3.2 Substation switchgear housing shall be grounded in a minimum of two locations.

6.3.3 Switchgear underground feeder conduit containing power cable shall contain a neutral wire 4/0 AWG, bare soft drawn, 7 strand copper with one end terminated to the switchgear ground bus.

6.3.4 Underground metal conduit located in switchgear shall be connected to the ground bus in the switchgear.

6.3.5 All above grade ground connections to circuit breakers and switchgear shall be 2-hole ground lugs, bolted or compression. All below grade connections shall be exothermic as specified in section 5.3.2 above.

6.4 Air Break and Three Phase Ground Switches

A gang operated three-phase ground switch shall be connected to the station ground grid in at least one location. The switch supporting structure shall not be considered part of the ground path. The vertical operating pipe for all gang operated switches shall be connected to a ground conductor that is attached to the ground grid. See, Entergy drawings SMGR01A0 and SMGR03A0.

6.5 Surge Arresters

6.5.1 Surge arresters installed on the brackets mounted on power and auto transformers shall be grounded using the shortest ground lead length possible and connected to the transformer tank ground pads. When arrester grounding pads are provided on the tank wall near the top, the ground lead shall be extended to the tank ground pads at the base and then tied into transformer ground loop. This will avoid using the transformer tank as a ground path for surge arresters.

6.5.2 Surge arresters mounted on separate support structures shall be grounded and connected to the ground grid in a loop. EHV surge arresters shall be individually grounded to the ground grid. Support structures shall not be used as a ground path.

6.5.3 Ground lead shall be minimum 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity.

6.6 Support Structures

6.6.1 All metallic substation support structures shall be bonded to the station grid with at least one connection per foundation. Bolted or compression 2-hole ground lugs or exothermic welding shall be used for the above ground connection.

6.6.2 Lightning masts shall be grounded at the base with no less than two (2) 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity connected to the substation ground grid.

6.6.3 All metal structures, equipment frames, and tanks shall be bonded to the ground grid using a 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity.

6.6.4 Structural steel is an adequate conductor for many grounding applications.
The need to run a separate ground conductor to mounted equipment should take into account the specific equipment and need for a direct low resistance ground conductor path.

6.7 Microwave towers

Microwave towers shall have a ground loop installed underground around the perimeter of the concrete foundation with ground rod for each leg and connected to the main ground grid. Perimeter ground grid conductor shall be no closer than twenty four (24) inches from foundation and twenty four (24) inches below finished grade (prior to the installation of a crushed rock layer).

7.0 FENCES

7.1 Fence Grounding

7.1.1 Unless shown otherwise on the substation grounding plan drawing all substations shall contain a perimeter ground located 3 feet on the outside of the substation fence

7.1.2 Every second line post of the substation fence shall be bonded to the ground grid. For substation yards exceeding 200' x 200', the bonding interval may be extended to every fourth line fence post. Fence fabric and barbwire strands do not require grounding. Fence posts shall be tied to the grid using a welded or bolted ground clamp attached to the inside web. Corner posts shall be grounded to the grid using a welded or bolted connection.

7.2 Swing Gate Grounding

7.2.1 All swing gates, including vehicle drive through and personnel walk through gates, shall be bonded to the gate post using an insulated 4/0 AWG flexible cable such as CADWELD FJ2G24 or FJ2Q24. If the gate post and gate frame is schedule 40 or larger steel pipe, direct exothermic connections to the steel shall be used.

7.2.2 All gate posts shall be bonded to the grid using an exothermic connection as shown in Entergy Drawing SMGR01A0.

7.2.3 All substation gate areas shall contain a 4/0 AWG copper ground mesh that extends 3 feet past the maximum gate swing area. It should be noted that a gate that swings out beyond the grid presents the absolute worst case touch potential hazard. (see Entergy Drawing SMGR01A0).

7.3 Horizontal Slide Gates Grounding

The sliding gates shall be grounded by means of a flexible, welding type, grounding cable suspended in loops or springs that extends and retracts with the gate movement. The sliding gate shall be grounded as recommended by the gate manufacturer and the supplier.

7.4 Privately Owned or Perimeter Fences

Substation fences should not be closer than 10 feet to any metallic component of a privately owned fence. In cases of good soil coupling, up to 80% of ground potential rise (GPR) can be transferred to the metallic portion of the privately owned fence. Where a privately owned or perimeter fence is closer than 10 feet, the Substation Designer shall be contacted. If applicable, see Drawing SMGR02A0 for fence isolation requirements.

8.0 GROUNDING OF BUILDINGS AND OTHER EQUIPMENT

8.1 Metal buildings used in substations shall be grounded to ground grid for personnel protection in a minimum of two places using a 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity.

8.2 Cable trays, AC panels, relay panels, carrier cabinets, metering, supervisory control cabinets, and all other equipment located inside the control house shall be grounded to ground grid. Cable trays or pits shall have a 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity ground wire installed in the entire length to provide a ground for above equipment. All cable trays, relay panels, cabinets etc. in the substation control house shall be grounded using a minimum 8 AWG copper wire.

8.3 All battery racks made of metal shall be connected to the control house common ground conductor using a minimum 8 AWG copper wire.

8.4 All enclosures, operating levers, metallic guards, hand rails, yard light supports, shall be connected to the ground grid.

8.5 All structure steel members including beams and steel angles, that the steel grating on top of an oil containment or other similar pits rests upon, shall be grounded. Subsurface drainage catch basin gratings shall not be bonded to the ground grid.

8.6 Equipment stored indefinitely at a substation site shall have the bushings tied together with a minimum 6 AWG, solid copper conductor and connected to the ground grid.

9.0 RAILS AND PIPES

9.1 All metallic water lines or sewer lines entering the substation yard shall incorporate a 15 kV insulating link at the fence line. An approximate ten (10) feet long section of non-conductive PVC line is sufficient to meet this requirement. All metallic lines within the substation grid area shall be connected to the ground grid.

9.2 Rail lines extending inside the fence shall be bonded to the ground grid with two (2) sets of 15kV insulating links installed, one (1) inside the fence and one (1) outside the fence, at an interval of ninety (90) feet to prevent a parked rail car from inadvertently shorting the insulated rail section. The railroad double gate shall be adjusted to provide three (3) inches of space between the top of the rails and the bottom of the gate to prevent shorting the insulated rail section.

10.0 OTHER OVERHEAD CIRCUITS

10.1 Shielding Wires

Where practical, shield wires and transmission line grounds (as applicable) shall be connected directly to the ground grid using a ground wire of 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity., Structure shall not be considered as the path to ground. When it is impractical to bond shield wires to the station grid, the wires shall be considered energized at 15 kV and safety precautions taken accordingly. See Entergy Drawing Number SMGR01A0 for details.

10.2 Distribution Circuit Neutrals

Distribution circuit neutral(s) shall be connected to the ground grid. Substation ground grid designs for underground connections shall include sufficient length grounding conductor "pigtails" for connection at each distribution circuit. The relative location of these connection points shall be indicated on the substation grounding plan.

Overhead neutrals shall be connected to the feeder bay structure steel and connected to the ground grid or alternatively and preferably connected directly back to the associated transformer neutral via conductor with rated ampacity at least equal to the overhead neutral conductor.

Neutrals of all overhead distribution circuits, that are dead-ended outside of the substation fence, shall, if practical, be brought to a common junction & connection point and tied to the substation ground grid at two different locations for redundancy. The common junction can be in an above ground plastic or a fiberglass splice box outside the fence.

Connections to the power transformer neutral or the ground grid shall be by means of a 4/0 copper or equivalent 19 strand No. 9 AWG Dead Soft Annealed copper clad steel conductor with 40% conductivity.

10.3 Communication Circuits

A serious hazard may result during a fault from the transfer of potential between the ground grid areas and outside points, such as communication and signal circuits. Communication circuits serving substations and switchyards should be designed with high voltage protection equipment (insulating or non-insulating transformers, fiber optics) against the effects of fault produced ground potential rise or induction voltages or both. This should be done in coordination with the appropriate communications company.

10.4 Transmission/Distribution Dead-end Structures

The last transmission and distribution line dead-end structures located outside the substation shall not be bonded to the substation ground grid unless specifically required by the substation ground grid design. If the structure is within 20 feet from the substation fence the designer shall include it in the WinGS model for analysis.

Bonding of the transmission line shield wire to the substation ground grid shall be as specified in Entergy TO0203; Transmission Line Design Criteria.

11.0 RESPONSIBILITIES

The Manager of Substation Design and Design Supervisors are responsible for assuring that all facilities are designed and constructed in accordance with this standard.

11.1 Interpretation
Interpretation of this standard is the responsibility of the Design Managers and Design Supervisors. Questions should be directed to the Manager of Transmission Design Basis.

11.2 Deviation
Deviations from this standard may be made only with the consent of the Manager of Substation Design, or an approved agent thereof. Any deviations granted shall be reported to Entergy Transmission Design Basis for consideration of inclusion in the standard. No other employee is granted independent authority to grant deviations.

11.3 Regulatory Requirements
This document contains activities addressing FERC/NERC compliance commitments. Document preparers shall review document number TD-ERS-FAC-001 to verify revisions to this document do not reduce compliance with the regulatory commitments.

12.0 ACKNOWLEDGMENTS

13.0 ATTACHMENTS
None

19#9 WIRE LENGTH PER GATE SPAN

NOMINAL ROLL GATE OPENINGS	LENGTH		WEIGHT PER
	FT.	IN.	LBS.
20' ROLL GATE	33	0	23.3
30' ROLL GATE	47	0	33.2

BILL OF MATERIALS

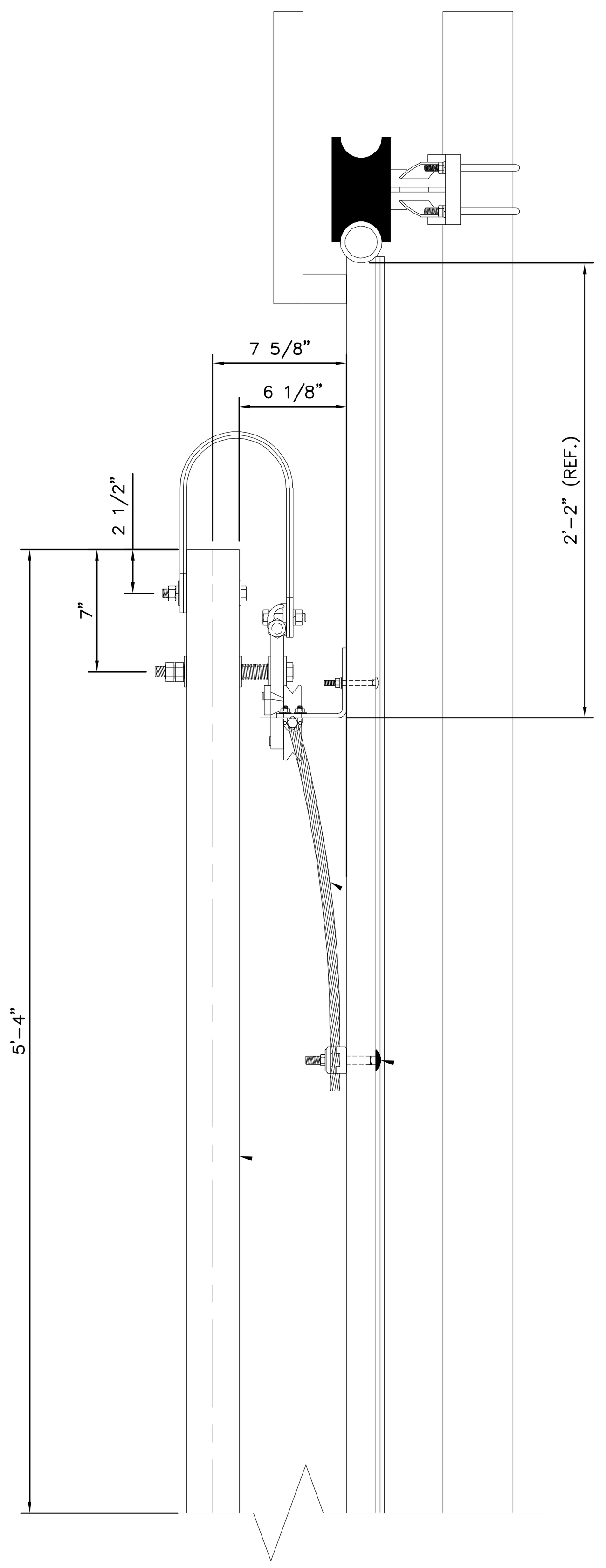
MARK#	CAT ID	UNIT	DESCRIPTION	COMMENT
I004	0000023122	LB	WIRE, GROUNDING, COPPER, SOFT DRAWN, BARE, 4/0 AWG, 7–STRAND, 1000 LBS REELS	
I069P	0032166555	EA	CARTRIDGE, EXOTHERMIC, #200 PLUS CHARGE, WELD, ELECT	
I401	0032127987	FT	WIRE, CAMO COPPERWELD, ANTI–THEFT, 19 #9 AWG, 40% CONDUCTIVITY, 1000 FT REEL	
I198	0032050044	EA	MOLD, EXOTHERMIC, PARALLEL, 19#9 STR TO 4/0 STR, HORIZONTAL	
U00X	–	EA	SUPPORT POST, 3"x3"x3/16" SQUARE TUBING, 9FT LENGTH, A500 STEEL, GRADE B, HDG OR POWDER COATED	CONTRACTOR SUPPLIED
Z00X	0322221225/EQUIVALENT	EA	TROLLEY GROUND KIT OR EQUIVALENT	

ASSEMBLY NOTES:

1. DRAWING DEPICTS LEFT CANTILEVER ROLL GATE. FOR OPEN RIGHT ROLL GATES, TROLLEY GROUND ANGLE IS ON THE INNER LEFT SIDE OF GATE FRAME. FOR OPEN LEFT ROLL GATES IS ON THE RIGHT SIDE OF GATE FRAME AS WELL AS ROTATED 180 DEG.
2. DIMENSIONS WILL DIFFER FOR EACH GATE OPENING DUE TO DIAGONAL SUPPORT DIRECTION AND VERTICAL COLUMN SPACING PER FRAME.
3. ADJUST HEIGHT OF TROLLEY GROUND ANGLES TO WHERE 5/16" MOUNTING HOLES WILL HIT THE OUTER MOST COLUMNS AND NEXT DIAGONAL (OR HORIZONTAL) FRAME SUPPORT ON CENTER.
4. ENSURE THAT TROLLEY GROUND ANGLES ARE LEVEL AND ATTACHED AT THE SAME HEIGHT TO HELP DETERMINE 19#9 WIRE/ TROLLEY GROUND HEIGHT.
5. ALLOW 19#9 CONDUCTOR WIRE TO HAVE A NATURAL ARC BEFORE CONNECTING TO GATE FRAME. MAKE SURE THERE ARE NO KINKS OR LOOSE/FRAYED WIRES BEFORE PULLING TENSION. SEE CHART 1: 19#9 WIRE LENGTH PER GATE SPAN FOR DETERMINING AMOUNT OF 19#9 CONDUCTOR WORE TO PULL ACROSS GATE FRAME.
6. WRAP BOTH ENDS OF 19#9 WIRE FOR TROLLEY GROUND WITH ELECTRICAL TAPE TO PREVENT FRAYING.
7. USING THE TURN BUCKLE, PULL ENOUGH TENSION ON 19#9 WIRE SO THAT THERE IS LESS THAN OR EQUAL TO 1" OF SAG IN THE MIDDLE OF THE SPAN.
8. DO NOT OVER–TIGHTEN 19#9 WIRE ACROSS GATE SPAN. AN OVER–TIGHTENED WIRE MAY CAUSE GATE WARPAGE OR DIFFICULTY CLOSING.

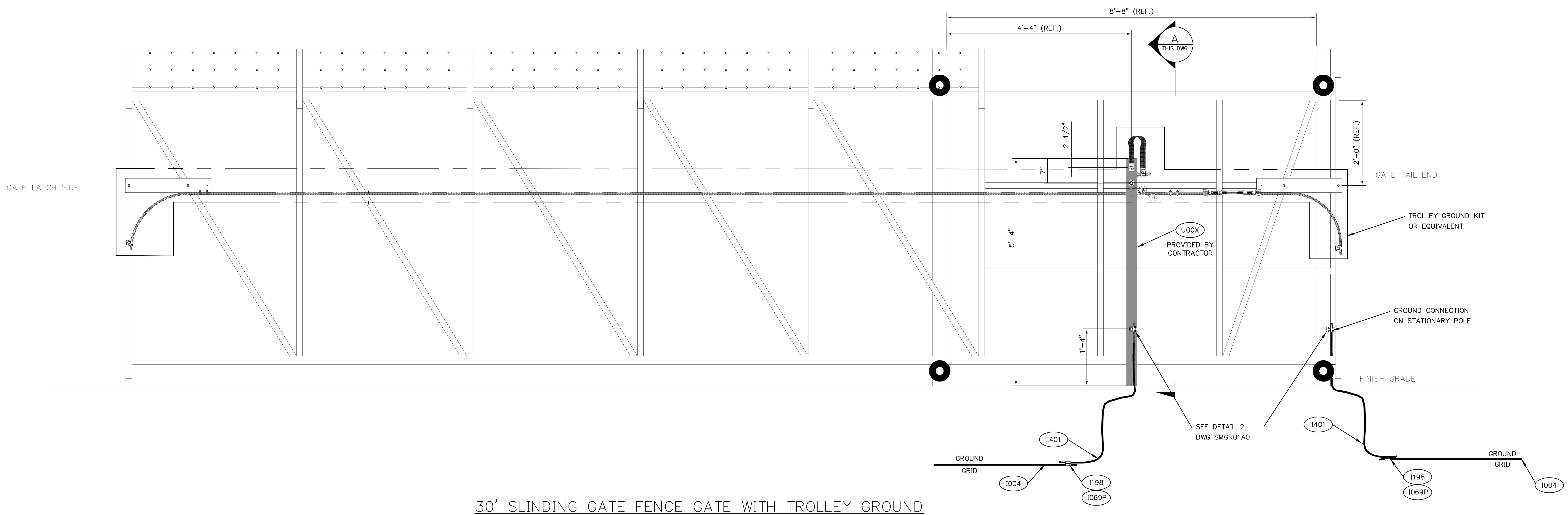
GENERAL NOTES:

1. GROUNDING SPECIFICATION SF0202 SHALL BE USED ALONG WITH THESE DETAILS.
2. VIEW OF SYSTEM IS FROM INSIDE THE SUBSTATION WITH THE GATE IN THE CLOSED POSITION.
3. THE CONDUCTOR WIRE FOR THE GATE SPAN IS DEPENDENT ON THE SIZE OF THE GATE AND WILL BE CUT TO LENGTH IN THE FIELD.
4. USE WIRE BRUSH AND APPLY INHIBITOR COMPOUND TO ALL GROUNDING CONNECTORS AND MATING MATERIAL WHERE NEEDED.



SECTION VIEW: A–A

A SECTION
THIS DWG SCALE: N.T.S.



30' SLINDING GATE FENCE GATE WITH TROLLEY GROUND
VIEW FROM INSIDE SUBSTATION (CLOSED)

1 DETAIL
THIS DWG SCALE: N.T.S.

REFERENCE DRAWINGS:

STANDARD GROUNDING PLAN (DETAILS 1–10)	SMGR01A0
STANDARD GROUNDING PLAN (DETAILS 11–15)	SMGR02A0

REFERENCE STANDARDS:

SUBSTATION GROUNDING DESIGN GUIDELINE	STD# SF0201
SUBSTATION GROUNDING SPECIFICATION	STD# SF0202

4/21/2023
kwebbel

NO.	DATE:	REVISION	BY:	CHK:	APPR:
0	06/21/23	NEW GND DETAIL FOR STD SF0202	KNW	KNW	MCW

ENTERGY SERVICES, INC
Substation Standard
SLIDING FENCE GROUNDING
GROUNDING DETAILS

STD NO. SF0202 | SCALE: 1"=0'-1"

entergy

No. SMGR06A0

PLOT 1=1 | SH. 1 OF 1