

Bill Petersen

President, Protection Technologies Inc.

Presents

Recommended Practice for Establishing Ground Potential Rise (GPR) and Zone of Influence (ZOI)

With concurrence by

Pat Hawkins, Joe Boyles, Randall Mears, Tristan Harris, Jim Furey, Robert Harris

RLH Industries, Inc.

GPR fault current practical applications

Presenting a “Simplified loop GPR” circuit diagram to an average power relay engineer, who is given the task of determining fault current (I_{GPR}) values for a specific power location, will more than likely result in quoting the current specifications for the outgoing line relay under buss fault conditions. This is not the fault current value that should be used by the telco electrical protection (or ICEP) engineer to determine actual GPR and ZOI conditions. Experience has shown that these values have been overestimated by as much as a 10:1 ratio. The reduction in actual¹ fault current paths entering the grid impedance will produce “REALISTIC” values of fault current, thereby reducing the GPR and ZOI² of the power facility under study.

As can be seen in **Figure 1**, only that portion of fault current that returns through the earth and enters the substation ground grid impedance contributes to actual GPR^{1,3} levels.

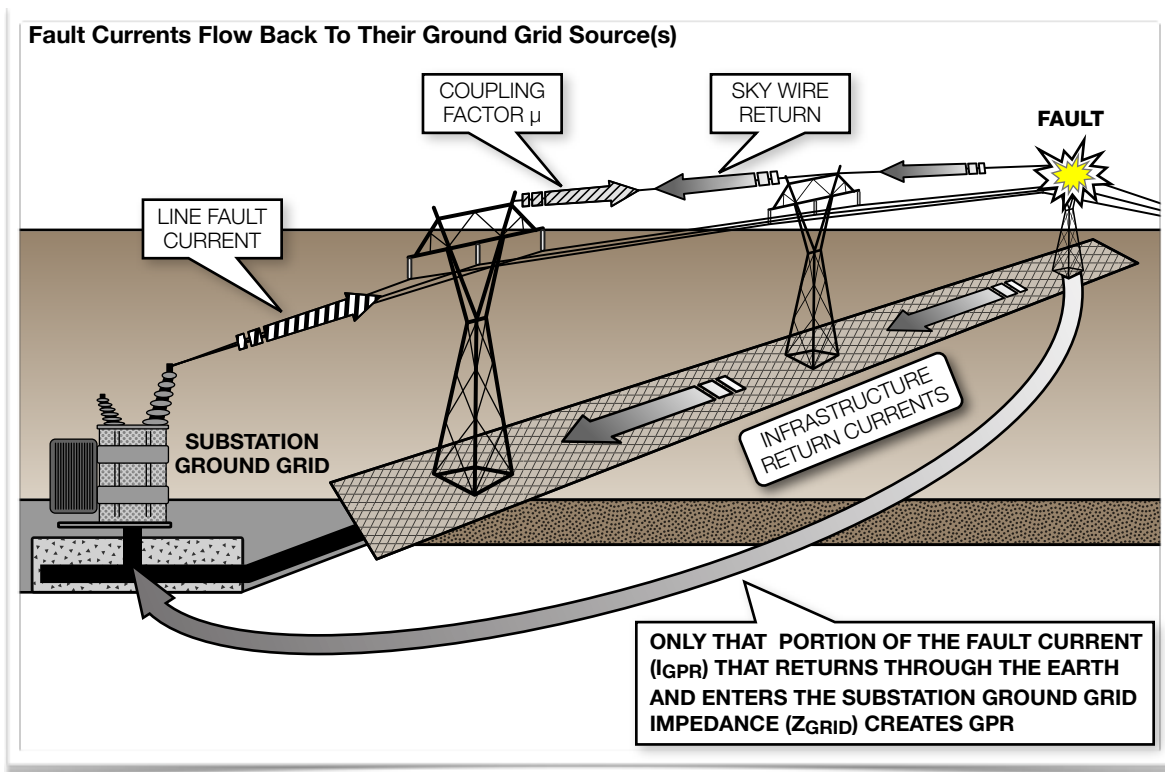


Figure 1 - Fault current return paths

¹ IEEE Std 367, *Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault*

² IEEE Std 487, *IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations*

³ IEEE Std 80, *IEEE Guide for Safety in AC Substation Grounding*

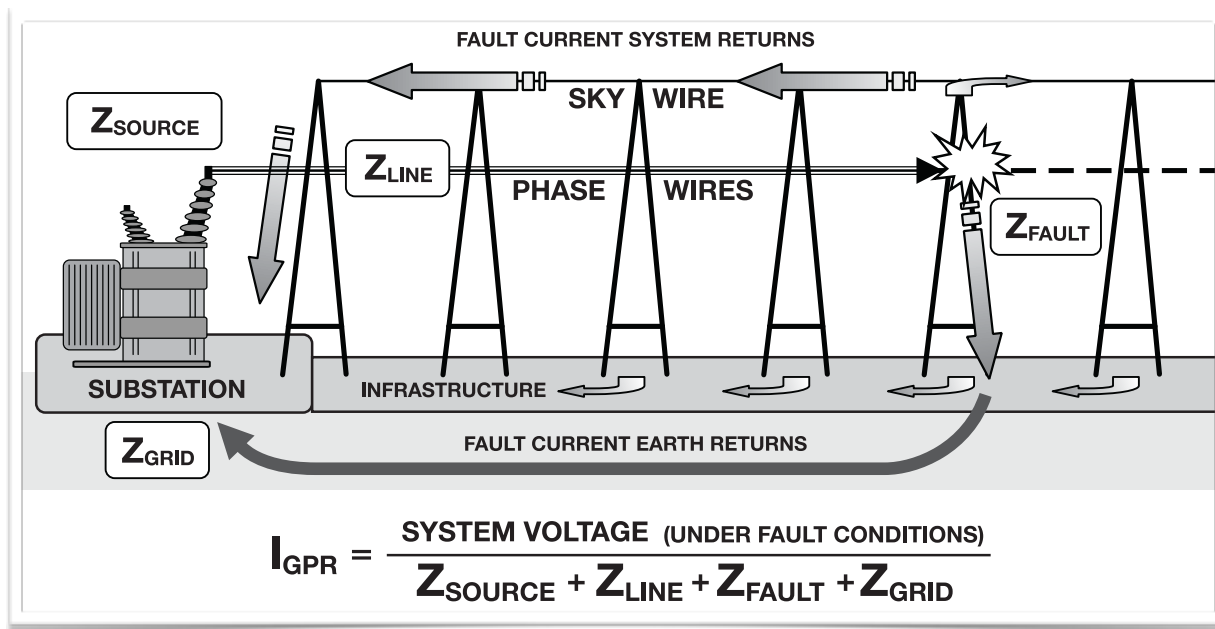


Figure 2 - Realistic fault current (I_{GPR}) factors

As shown in Figure 2 the GPR current value will always be a function of the system voltage, under fault conditions, divided by the current path impedances that only flow through the grid impedance of the substation under study.

Fault currents returning through the metallic power system components directly, or indirectly, connected to the grid do not contribute to the GPR magnitude. In order to arrive at a realistic GPR and resulting ZOI, factors which limit fault currents should be considered by the power relay and or telco ICEP engineer.

The reducing factors used should be backed by solid engineering judgment, and a working knowledge of the power networks under their control. The current limiting factors should always include the source generator and/or transformer impedance(s), characteristic line impedances, sky wire (return current with around 20% opposing μ coupling factor)⁴, MGN neutral networks, arc resistance, ground grid impedance at the substation under study, and most important the community metallic infrastructure⁴. The amount of reduction will always depend on local conditions within their network, and cannot be determined on a blanket basis.

Z_{SOURCE} (Transformer impedance) is derived from the percent loss and transformer KVA base. The source impedance should never be assumed to be 0 ohms. Under most fault conditions the **Z_{SOURCE}** and **Z_{FAULT}** are the two main factors that influence actual **I_{GPR}** values.

⁴ IEEE Std 367, *Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault*

The percent loss value is a function of the transformers capacity to produce rated power under full load conditions. The percent impedance should be converted to ohms per phase on either the high or low side of the transformer using the following formula:

$$Z_{SOURCE} = \frac{10(\% LOSS)(KV^2)}{KVA}$$

Note: If it is a (6 % Loss) transformer use '6' for this value

The sub-transient reactance of a generator occurs at the instant of a fault, and is used for calculating the initial symmetrical fault currents. This reactance continuously decreases for approximately 3 cycles after fault initiation. After that time period the generator transient reactance should be used. It also decreases continuously, but is assumed to be steady at this value for approximately 15 cycles. Actual reactance values should be obtained from the generator specifications. For transmission transformers the reactance is usually much larger than the resistance, and the impedance is often considered to be entirely reactive with the resistance neglected. However, in distribution transformers the reactance is much smaller and both the resistance and reactance must be considered⁵.

Z_{LINE} (Line impedances)

60Hz reactance in ohms per mile average approximately 0.8 ohms. If a more precise value is available for a specific power line it should be used instead. Another value used in determining the impedance of a line is the shunt-capacitive reactance. This value averages around 0.2 megohms per mile. It is significant to note that regardless of the voltage, conductor size, or spacing of a line, the series reactance and shunt-capacitive reactance remain at these average values.

Z_{FAULT} (Arc and tower ground impedances)

Unless a fault occurs at or very close to a station, the impedance of the circuit can *considerably* decrease the levels of fault current. Another factor that must be considered is the arc resistance in series with the grounding resistance of a skywire or MGN system.

The grounding resistance depends on the tower footing resistance, the skywire connections to each tower, the presence of counterpoises, and the location of the fault. For faults at a greater distance from the source(s), the grounding resistance will be much smaller than that seen at a single tower footing. In reality, a power line with skywire or MGN configuration appears as a matrix of parallel (grounding) and series (skywire) impedances in series with the Arc Ω creates an average Z_{FAULT} value. The following average values of Z_{FAULT} may be used for fault impedance that take into account both arc and tower grounding resistances between a power source and a phase-to-ground fault⁶:

Z_{FAULT} ≈ 0 Ω for station bus faults

Z_{FAULT} ≈ 15 Ω for lines with skywires

Z_{FAULT} ≈ 50 Ω for lines without skywires

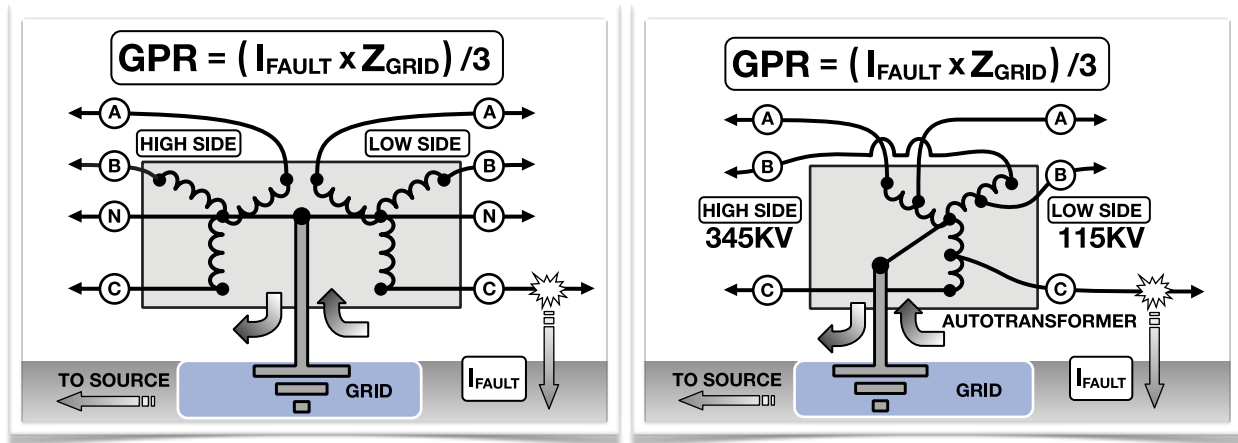
⁵ Westinghouse Electric, *Electrical Transmission and Distribution Reference Book*

⁶ Bodle, D. W., Ghazi, A. J., Syed, M., and Woodside, R. L. *Characterization of the Electrical Environment*, University of Toronto Press, 1976

Z_{GRID} (Station ground grid impedance)

For smaller grounding grids the impedance should be determined using the recommendations of IEEE Std 81. For larger grids the impedance should be determined using the recommendations of IEEE Std 81.2 and or IEEE Std 367. For new grids that have not been put into service and tested, estimated grid impedance can be determined using the formulas contained in IEEE Std 367.

Transformer Fault Currents



Figures 3a, 3b – Transformer net fault current phase angles

The power engineer should also consider positive sequence fault current phase shifts in certain transformer windings^{7,8}. Two examples are the Y-Y and autotransformer shown in Figures 3a, 3b. The windings within these transformers have a *common path* between the high and low sides that provide a fault current path back to the main generation source(s).

Under fault conditions the current flows entering the ground grid impedance are usually out of phase with each other. The phase angle of these two opposing current flows should be analyzed to determine the maximum expected line-to-ground fault current levels flowing through the ground grid impedance. The resulting current flowing through the ground grid will be approximately one third ($1/3$) that expected if the original low side current is used for GPR studies.

⁷ IEEE Std 367, *Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault*

⁸ Westinghouse Electric, *Electrical Transmission and Distribution Reference Book*

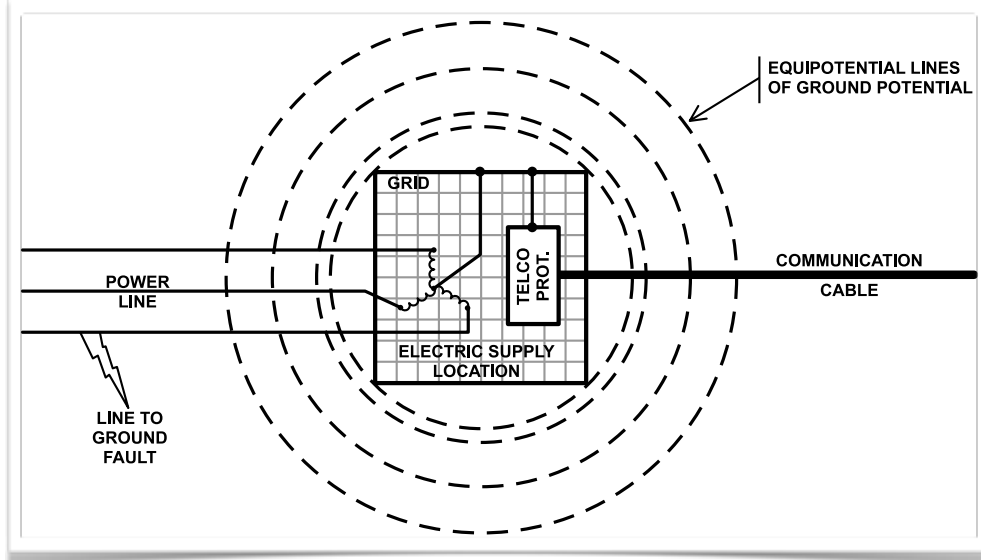


Figure 4 – Theoretical illustration of electric supply location ground potential⁹

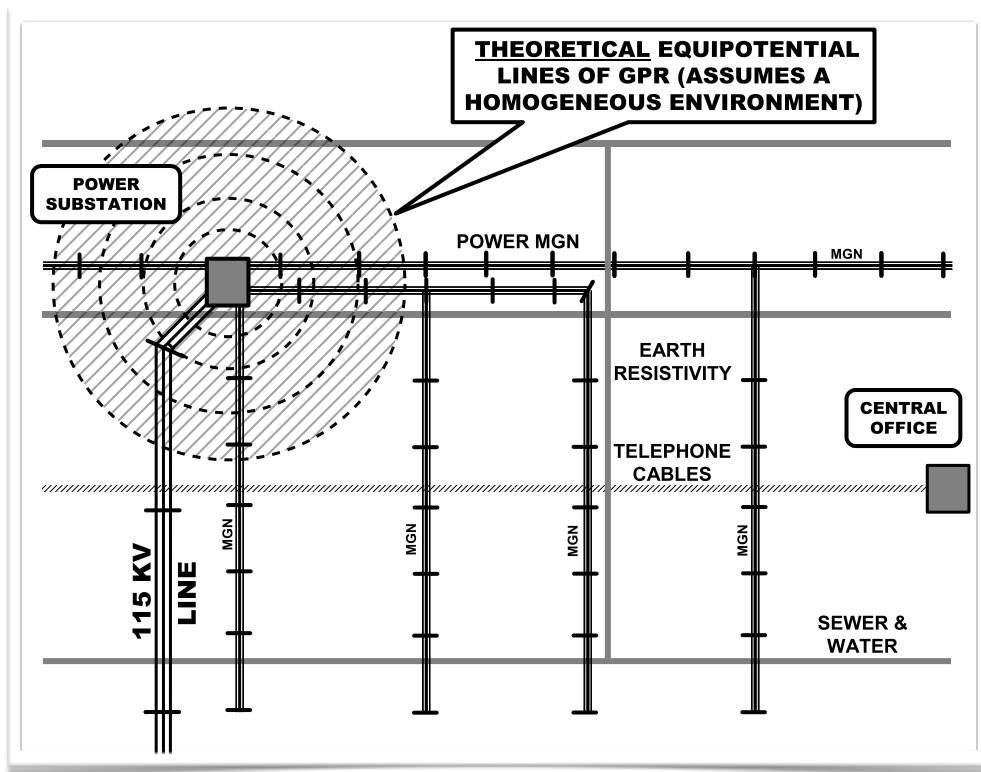


Figure 5a – Theoretical conditions (assumes homogeneous environment)¹⁰

⁹ IEEE Std 487, *IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations*

¹⁰ Rajotte, Yves; De Sève, Jean; Fortin, Jacques; Lehoux, Richard; and Simard, Georges. *Earth potential rise influence near HV substations in rural areas* CIRED 18th International Conference on Electricity Distribution, Turin, 6-9 June 2005.

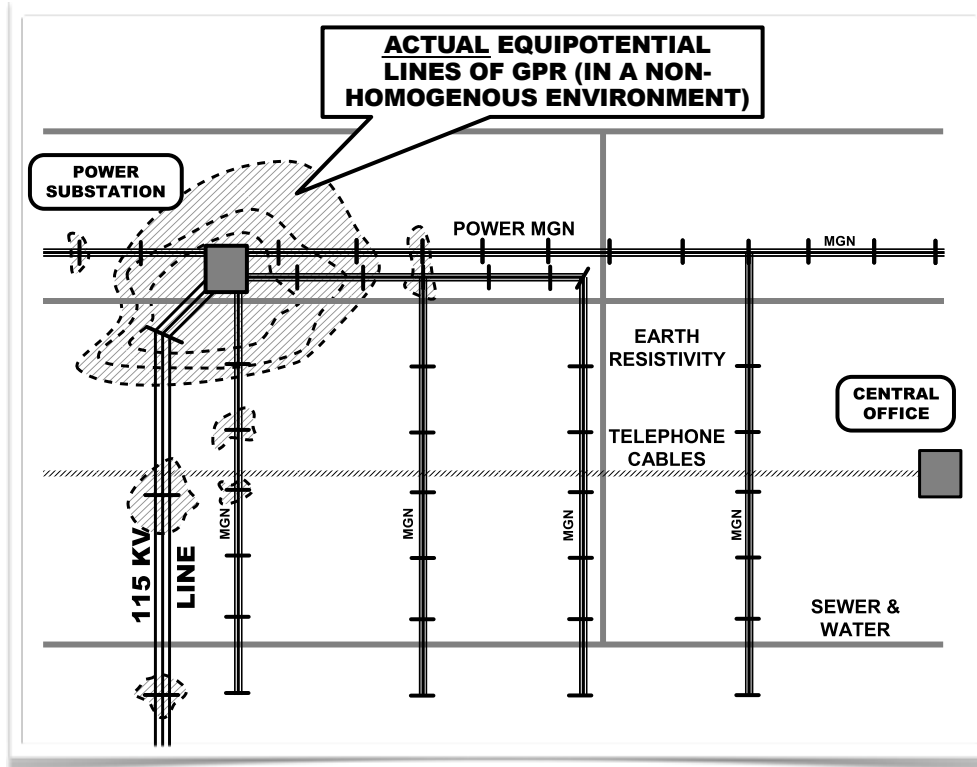


Figure 5b – Actual field conditions (non-homogeneous environment), illustration of substation ground potential rise equipotential lines¹¹

Figure 5a illustrates theoretical equipotential GPR voltage lines, as depicted by Figure 4 in numerous technical publications, with the assumption that earth resistivity $\rho(\Omega\cdot m)$ measurements are homogeneous and no metallic infrastructures are attached to the grid under consideration, including any power facilities feeding the grid. This theoretical condition never occurs in a working power system.

Figure 5b illustrates a typical GPR profile with non-homogeneous conditions with metallic infrastructure influences. During GPR fault conditions, the equipotential GPR profiles around a grid, and metallic structures in, on, or adjacent to it, become a function of the ground return fault currents returning back to their source, or sources, in the power network through a non-homogeneous environment⁹. This non-homogeneous environment consists of, but is not limited to, the grid under consideration, multiple earth resistivity regions and layers, transmission tower and MGN grounding systems, sewer, water, and gas piping, rivers and lakes, train tracks, telecommunication cables, and their mutual bonding and grounding networks (collectively called either a metallic infrastructure or global earthing system).

¹¹ Rajotte, Yves; De Sève, Jean; Fortin, Jacques; Lehoux, Richard; and Simard, Georges. *Earth potential rise influence near HV substations in rural areas* CIRED 18th International Conference on Electricity Distribution, Turin, 6-9 June 2005.

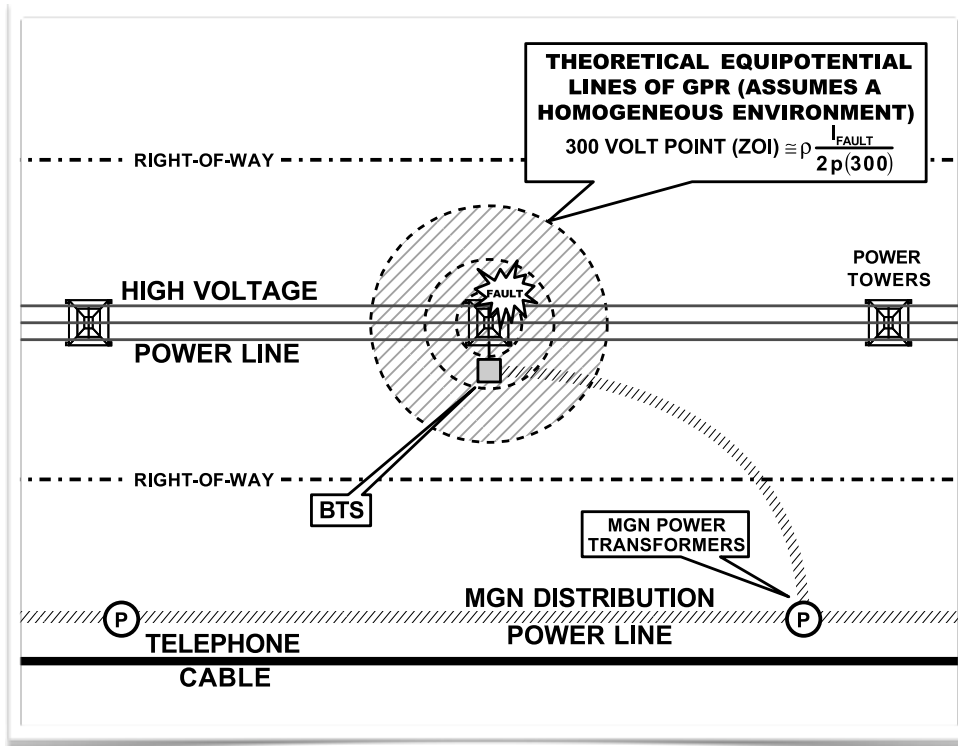


Figure 6a — Theoretical conditions (assumes homogeneous environment) of a BTS radio site, located on a power transmission line, ground potential rise equipotential lines.

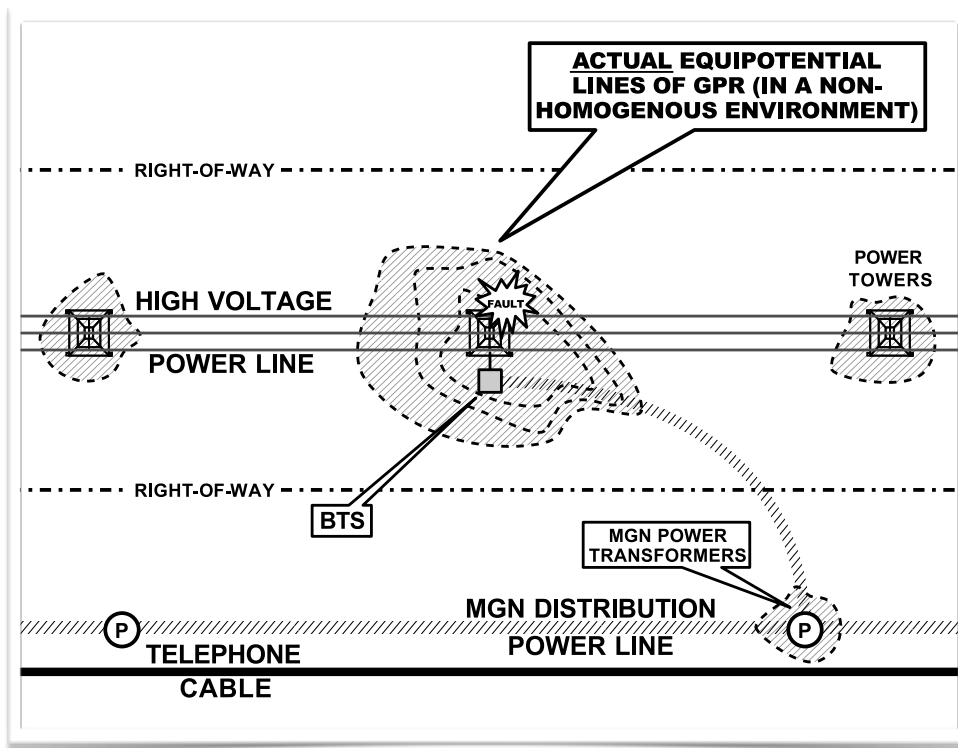


Figure 6b — Actual field conditions (non-homogeneous environment), illustration of a BTS radio site, located on a power transmission line, ground potential rise equipotential lines.

Figure 6a illustrates a theoretical GPR profile for a small grid on a power transmission line assuming homogeneous conditions with no metallic infrastructure influences; also depicted in various standards. The theoretical 300 volt ZOI metric value for small grids (single ground rods only) is derived from the following relationship shown in this equation¹²:

$$\text{300 Volt Point (ZOI)} = \rho \left(\frac{I_{\text{FAULT}}}{2\pi(300)} \right) \text{ Where } \rho \text{ is the earth resistivity at the grid location}$$

I_{FAULT} is the fault current flowing through the small grid

Due to the non-homogenous environment of grounding grids in working power systems, the theoretical ZOI's derived from the above formula also never occurs. Notice also that fault currents (including lightning strike currents) on power transmission lines are distributed to 5-10 adjacent towers via their common skywire ground protection system. The net result is a substantially smaller 'de facto' ZOI. This fact must also be considered when placing the CFJ.

Localized GPR, or Ground Potential Difference (GPD), is a function of current flow through individual impedances. As an example, if you have 1000-1500 MGN "grounds" within the EPRI curve ZOI¹¹, each and every ground will carry a portion of the fault current return(s) as a function of their individual ground and or return path(s) impedances. This makes for very complex soil voltage profiles. These calculation efforts are useless in a MGN network as the GPR is transferred by all ground links.

Knowing that all customers and metallic equipment along the power distribution network are referenced to the MGN voltage, then the ZOI concept is non-applicable for equipment located inside this MGN network. Near a High Voltage (HV) tower the profile looks more like the Figure 6b non-homogeneous diagram and will never be uniform. However, there will be Ground Potential Difference's (GPD) between all of these "grounds" during substation fault conditions. In urban or city locations this effect is greatly reduced¹³ through the common bonding and grounding practices of the NEC and NESC standards. Therefore, the step and touch effects inside an MGN urban network are usually reduced to acceptable working levels¹⁴.

Neutral connections transfer GPR to distances exceeding one kilometer in rural areas¹⁵. In urban areas the metallic infrastructure, from all practical points of view, fixes the reference volts at a much lower value¹⁶. In those cases, telecommunication cable sheath isolation is useless in preventing GPR transfer voltages toward the telecommunication network. **From a practical point of view, when installing a fiber optic cable, the ZOI limit can be fixed as the first connection point to a structure connected to a multi-grounded neutral network.**

In many situations, using dedicated wire-line facilities for the entire distance from the electric supply location to the remote location may not be technically feasible (interference susceptibility) or economically practical. Dedicated fiber optic

¹² Sunde, E. D., *Earth Conduction Effects in Transmission Systems*, Dover Publications, New York 1968.

¹³ Lipavsky, P.; Nienaber, R.; *Measurement of Ground Potential Difference at Power Substations*, IEEE Transactions on Power Delivery, Vol. 6, No. 1, January 1991

¹⁴ Rajotte, Yves; De Sève, Jean; Fortin, Jacques; Lehoux, Richard; and Simard, Georges. "Earth potential rise influence near HV substations in rural areas" CIREN 18th International Conference on Electricity Distribution, Turin, 6-9 June 2005

¹⁵ CEATI report "Electrical protection of telephone cable serving HV/MV substation" (available by the end of 2008)

¹⁶ Leonid Grcev and Velimir Filiposki "Zone of Influence of Ground Potential Rise on Wire-Line Communication Installations in Urban area" *Electromagnetic Compatibility*, 1997. IEEE 1997 International Symposium.

cable may be merged with a general-use telephone plant at a location outside the zone of influence of the station GPR, or as an alternative, **the dedicated cable can be merged with general-use cable at a point where the station GPR coordinates with the dielectric strength of the general-use cable**¹⁷.

Today's general-use cable has a dielectric strength around 20kV, and will only be subjected to that level if it is not associated (bonded to) the local power MGN system per the NESC standards. Fiber optic isolation inside the ZOI prevents the risk of wire-line conductors overheating due to high conducted (GPR or GPD) or induced¹⁸ current flows, and eliminates transferred voltages¹⁹ in or out of the electric supply location. *Fiber optic cable has an infinite dielectric withstand capability and is immune to induction within the ZOI.*

Safety Considerations

There are three items¹⁸ from a safety point of view that must be considered when placing communication facilities within high voltage environments.

Step voltage: The difference in surface potential experienced by a person bridging a distance of 1 m with the feet without contacting any grounded object.

Touch voltage: The potential difference between the ground potential rise (GPR) and the surface potential at the point where a person is standing while at the same time having a hand in contact with a grounded structure.

Transferred voltage: The 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.

When the MGN links are removed through the use of an AC isolation transformer (see Figure 11), non-metallic (no tracer wire or other metallic conductors) fiber optic cable eliminates these safety concerns for one major reason; it's not a current conductor. Therefore, it doesn't contribute to step, touch, or transferred voltages. Wire-line (copper) installations are current conductors so all three must be considered, especially transferred voltages¹⁸.

¹⁷ IEEE Std 487, *IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Supply Locations*

¹⁸ IEEE Std 367, *Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault*

¹⁹ IEEE Std 80, *IEEE Guide for Safety in AC Substation Grounding*

Locating Copper Fiber Junction's (CFJ) for wireless located on transmission towers

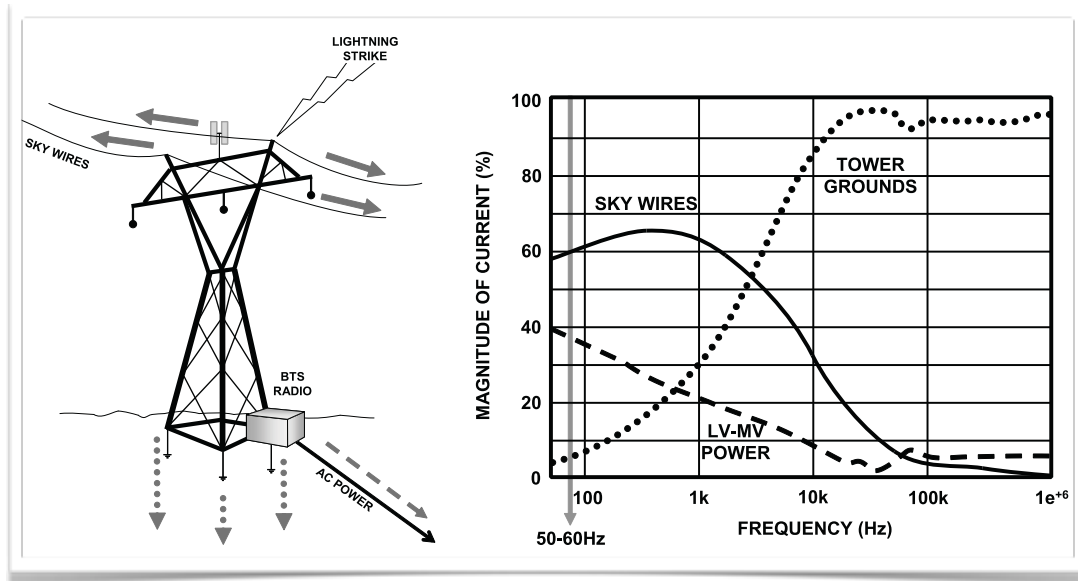


Figure 7 – Possible lightning current distributions for a BTS on a power tower.

Lightning and 60 Hz fault currents, for BTS's located on a high voltage transmission structures, can flow on three predominant conducting paths back to their source, or sources, within the power grid. The first is the tower sky wire system (when used) grounded to earth and near tower groundings in, on, or adjacent to the lines right of way. The second is the tower and BTS combined grounding system. The third is through the local power system ground that provides power to the site. Figure 7 depicts these current distribution paths^{20, 21}.

The distribution, or current magnitude on the various paths, becomes a function of the path impedance at the various fault frequencies. At the fundamental 60 Hz power frequency the sky wires conduct approximately 60 % of the fault current while the tower/BTS grounding system conducts less than 10 % to remote earth (low frequency GPR). The remaining current follows the local ac power grounding network and distributes it throughout the community²². At lightning frequencies approaching 10-100k Hz the inductive characteristic of the sky wires, and local power, present higher impedances, while the tower presents a lower impedance to ground and conducts over 90% of lightning fault current (high frequency GPR).

²⁰ Grcev, Leonid; van Deursen, A.P.J.; van Waes, J.B.M., *Frequency domain analysis of the lightning current distribution to ground at the transmission line tower with cellular phone base station*, IEEE International Symposium on Electromagnetic Compatibility. Vol1, pages 637-640. May 2003.

²¹ Grcev, Leonid; van Deursen, A.P.J.; van Waes, J.B.M., *Time domain analysis of the lightning current distribution at the HV tower with GSM system*, 2003 IEEE PowerTech conference, June 2003.

²² Rajotte, Y; Bergeron, R; Chalifoux, A; Gervais, Y, *Touch voltage on underground distribution systems during fault conditions*, IEEE Transactions on Power Delivery, vol 75, pages 1026-33. April 1990.

Locating the ZOI very accurately is not crucial, since inhomogeneities in the earth and presence of metallic infrastructures will distort the ZOI. The important point is to locate the CFJ so that the GPR is not high enough to cause dielectric breakdown in the general-use cable.²³

We should be concerned with Ground Potential Difference (GPD)²⁴ within rural, urban, or urbanized environments that would create unsafe touch potentials or cause dielectric breakdown in general-use (copper based) cables, while also considering the equalizing effects and safety record of existing metallic utility grounding grids that have been placed using NEC and NESC standards.

In urban and urbanized areas, with extensive metallic infrastructures, the GPD can be assumed to be low²⁵ for all practical purposes. In those cases, telco cable sheath isolation becomes useless to prevent GPR from transferring into the telecommunication network. The net result is very large areas within a community rising and falling in potential at the same time resulting in smaller current flows between individual bonded and grounded structures. **Again, from a practical point of view, when installing a fiber optic cable, the ZOI limit can be fixed as the first connection point to a structure connected to a multi-grounded neutral network.**

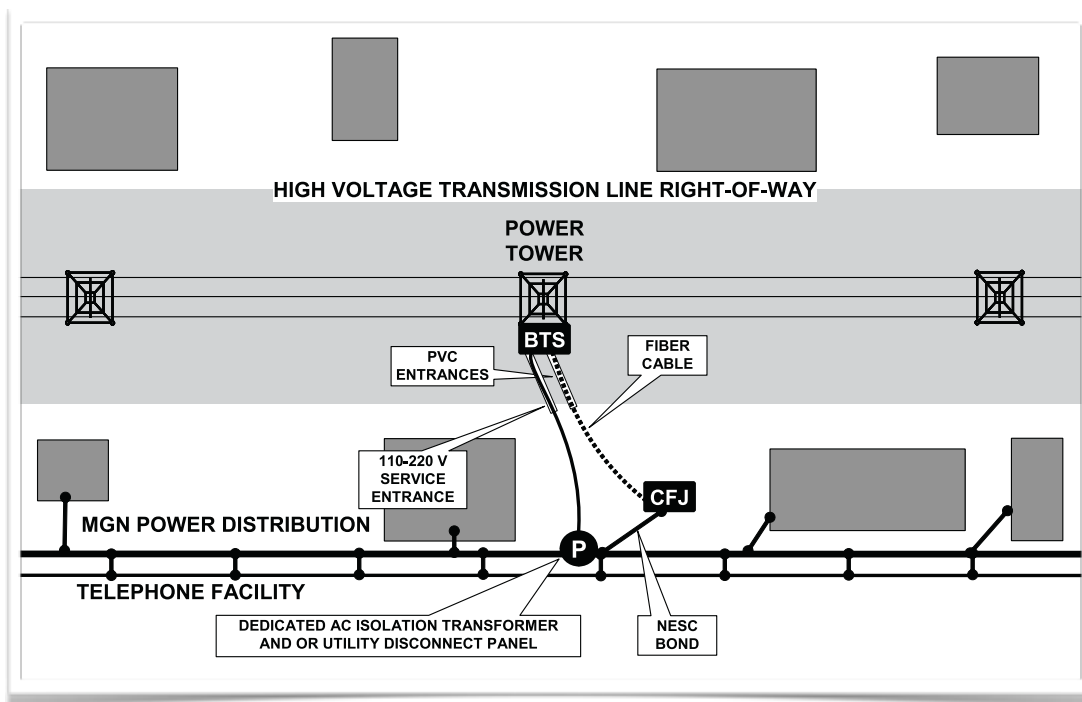


Figure 8 – In urbanized areas the ZOI is defined as the distance to the edge of the high voltage power line right-of-way.

²³ Jeffrey Bolksiner; SR-3966 *Electrical Protection Considerations for Serving Wireless Facilities at High Voltage Towers*, 1996 by Bellcore

²⁴ Lipavsky, P.; Nienaber, R.; *Measurement of Ground Potential Difference at Power Substations*, *IEEE Transactions on Power Delivery*, Vol. 6, No. 1, January 1991

²⁵ Leonid Grcev and Velimir Filiposki, *Zone of Influence of Ground Potential Rise on Wire-Line Communication Installations in Urban area*, *Electromagnetic Compatibility*, 1997. IEEE 1997 International Symposium.

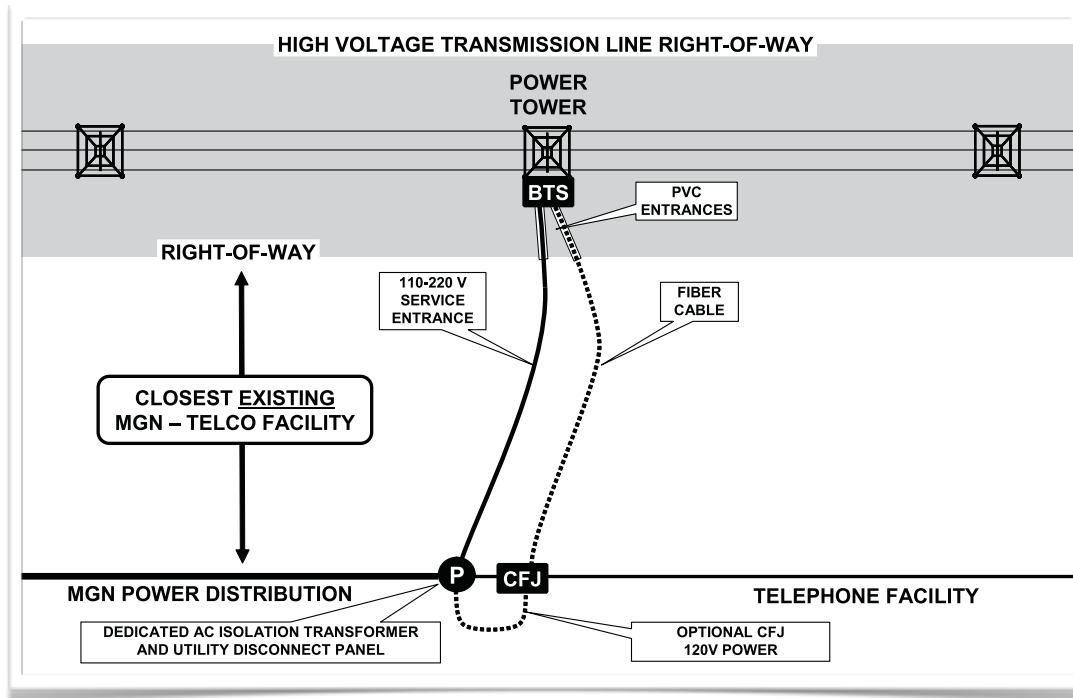


Figure 9 – In rural areas the ZOI is defined as the closest existing MGN-telco joint use access point.

Where a wireless site is located on a high voltage line and it receives ac power from a locally derived MGN power system as depicted in Figure 8 (urbanized) and Figure 9 (rural), the CFJ may be placed at an existing joint use MGN power and wire-line cable facility (not located within the power line right-of-way) only if the following safety requirements are met by the serving power company and or the wireless site owner(s):

- 1) All step, touch, and mesh voltage reduction measures at the BTS's must be met. See Figure 10 for details.
- 2) The CFJ must be placed adjacent to and bonded (per NEC and NESC) to the local MGN grounding system. It is recommended that a ring of bare copper wire be placed at a depth of 12" in the soil encircling the CFJ and bonded to the CFJ ground to reduce touch and step potentials. Working on an insulated surface and or blanket at this location also reduces the effects of touch potential as well as power line capacitive coupling on wire-line cable pairs.
- 3) If AC power is required for the CFJ fiber optic system, it must obtain that power at the same UTILITY SERVICE DISCONNECT 120-240 panel serving the cell site. It is highly recommended²⁶ that the site owner or serving power company provide an additional isolation transformer²⁷ per Figure 11. This is a critical requirement in rural installations as very high GPR voltage can be transferred along the neutral. Without neutral isolation touch and step voltage around telecommunication installations bonded to the neutral, at high voltage locations, can be a major concern.

In urban areas the magnitude of Ground Potential Difference (GPD) adjacent to power facilities within established metallic infrastructures is substantially lower than any Ground Potential Rise (GPR) values ever calculated, and well within established NEC and NESC worker safety standards. In North America there are hundreds of thousands of remote

²⁶ IEEE Std 1590, *IEEE Recommended Practice for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Using Optical Fiber Systems*

²⁷ ITU-T K.57 *Protection measures for radio base stations sited on power line towers*

digital carrier terminals and tens of millions of telco general use cables and their access points placed in, on, or adjacent to these same power transmission line electrical environments without adverse effects or abnormal worker safety issues.

VERY IMPORTANT NOTE: The IEEE-487 and IEEE-1590 do not give a local serving telco protection engineer the right to ‘dictate’ what the electrical protection values are. They are obtained by “mutual agreement” between the telco and their end users! If it is agreed that the edge of the ZOI is at the nearest telco access and MGN, where the two systems are bonded together (the de facto ZOI), then the CFJ locations meet the requirements of these recommendations!

Refer to the footnotes for three more IEEE documents that shed additional light on the subject.^{28, 29, 30}

Requirements for Power Tower Installations

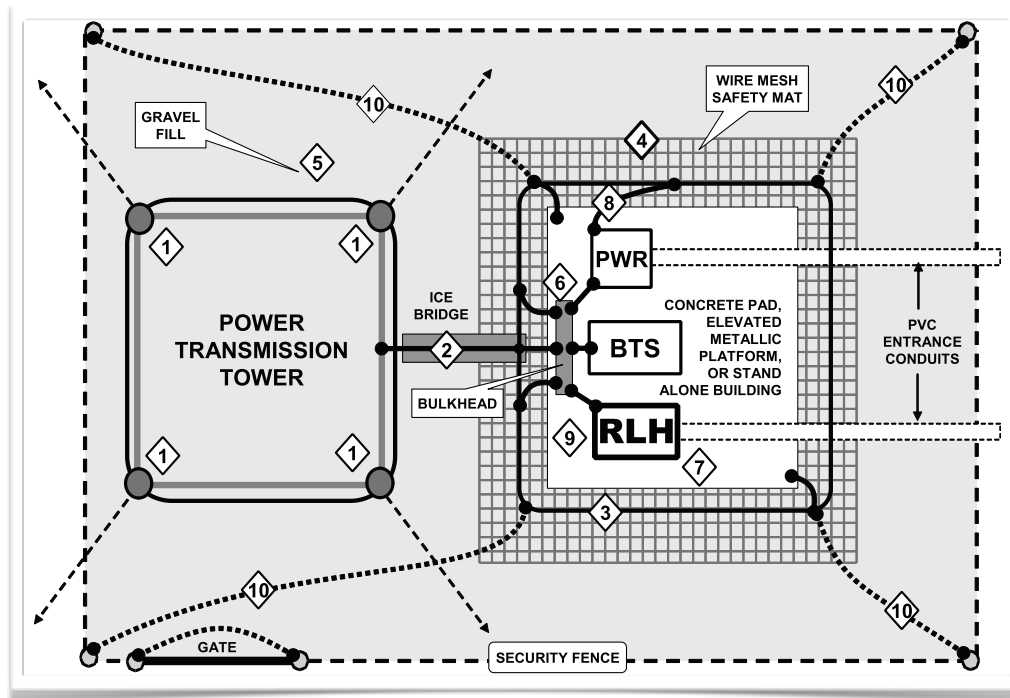


Figure 10 – Touch, step, and mesh voltage requirements for power tower installations.

The following notes correspond to the small numbered diamonds \diamond shown in Figure 10.

1. Joint Use Power Transmission Towers

At these specific locations it is recommended that an additional 2 AWG bare solid tinned copper wire ground ring be placed at a 24” depth and bonded to each tower leg with a listed bond. If a counterpoise is required, due to poor soil resistivity, extend a 2 AWG solid tinned wire approximately 30 ft-50 ft from each corner with ground rods (if possible) placed at each end and at 20’ intervals. The recommended depth of the counterpoise wire to be 24” and shall not contact any other metallic components at the site (i.e., fences). This will reduce touch and step potential.

²⁸ Leonid Grcev and Velimir Filiposki; *Zone of Influence of Ground Potential Rise on Wire-Line Communication Installations in Urban Areas*

²⁹ N. Mitskevitch, F. P. Dawalibi, J. Ma, and J.Liu; *GPR Zone of Influence of a Typical Electric Power Network*

³⁰ Y. Rajotte, J. Fortin, G. Lessard of Hydro-Quebec; *Safety Issues Related to the Connection of MV and HV Grounding*

2. **Ice Bridge Bond**

When the BTS radio is placed to the side of the power tower (as shown in Figure 9) the ice bridge should not be bonded to the tower structure! It should only be bonded at the bulkhead for equalization purposes. This will reduce touch and step potential.

3. **BTS Grounding Ring**

Place a 2 AWG bare solid tinned copper wire within 3 ft (+/- 15% tolerance) from edge of the concrete pad, elevated metallic platform, or building at a maximum depth of 2 ft. Ground rods must be placed a minimum of 3 m (10 ft) apart and or at each corner of the ground ring. This will reduce touch and step potential when the ring is bonded to the mat in item 4 below.

4. **Wire Mesh Safety Mat**

It is recommended at joint use power towers that a wire mesh safety mat (6" on center) be bonded to the ground ring and extended a minimum 6' from the edge of the pad or power tower foot print, whichever is the greatest distance. This will reduce touch, step, and mesh potential when covered with gravel fill as described in item 5 below.

5. **Gravel Fill**

For worker safety and to decrease step potential, a layer of clean crushed gravel a minimum of 3 "– 6" deep should be placed over the entire grid/mesh area. When a security fence is in place the clean crushed gravel should be placed within the total security fence area. See IEEE Std 80 for design details. For worker safety reasons do not use conductive asphalt for this application as conductive asphalt will increase touch and step potential.

6. **Bulkhead Ground Bar**

The bulkhead is the single point ground for the installation. All equipment or secondary protectors that require a ground or ground reference shall be bonded to this single point, either directly or with the use of a Master Ground Bar (MGB) located within 3 ft. of the bulkhead. Use individual listed grounding kits for each coax cable entering the BTS at this location. This will reduce touch and step potential for workers and provide voltage equalization for equipment at the site.

7. **Concrete Pad, Elevated Metallic Platform, or Stand Alone Building**

If a concrete pad contains rebar and or wire mesh it shall be equipped with external bonding connectors and bonded to the ground ring at a minimum of two opposing corners. If the BTS is placed on an elevated metallic platform or stand alone building it must also be bonded to the ground ring at a minimum of two opposing corners. The bonding wires must be a minimum 6 AWG copper wire. This will reduce touch, step, and mesh potential and provide voltage equalization for equipment at the site.

8. **AC Power Entrance Panel**

Commercial AC power service entrance cables must be placed in a PVC conduit (suitable for power cable pulling) at a minimum depth of 3 ft. to a point beyond the power corridor [ROW]. The entrance panel must be bonded directly to the ground ring at its closes location. If properly installed the BTS ring ground meets or exceeds the NEC Article 250 utility protection ground. If local codes require an additional ground rod, bond the ground rod to the ground ring. All power circuits that enter the BTS must be provided with primary (placed on the line side of the serving panel board) and secondary (placed on the load side of each 20A. circuit) protection. Some BTS manufactures provide secondary protection within their equipment that meet the secondary

requirement. All secondary green wire safety conductors must be placed within 3 ft. of, and bonded to, the bulkhead or MGB with a copper conductor sized per NEC Article 250-122.

9. High Voltage Protection (HVP)

Fiber optic cables must be placed in a PVC conduit (suitable for communication cable pulling) at a minimum depth 2 ft. to a point beyond the power corridor (ROW). Secondary protectors on the station side of the OEI interface and at the BTS shall be placed directly on, or bonded within 3 ft. of the bulkhead. This will reduce touch potential.

10. Fence and Gate Equalization Bonds

Use 2 AWG solid tinned copper wire exothermically welded to the ground ring and attached to each inside or outside corner fence post, and or gate post, with a listed wire clamp. Place at a minimum 12" depth. Wherever practical, due to magnetic coupling with the tower counterpoise wires (if used), cross at a 90° angle while maintaining a minimum 12" vertical separation. Do not bond these two grounding systems together at crossings. Place a 2 AWG solid tinned copper wire attached to each gate post with a listed wire clamp. Place a flexible bonding strap from each gate post to the movable gate section(s) with listed clamps. If the metallic posts are not set in concrete place an additional ground rod at each post location. This will reduce touch potential.

Wireless Site Isolation Transformers

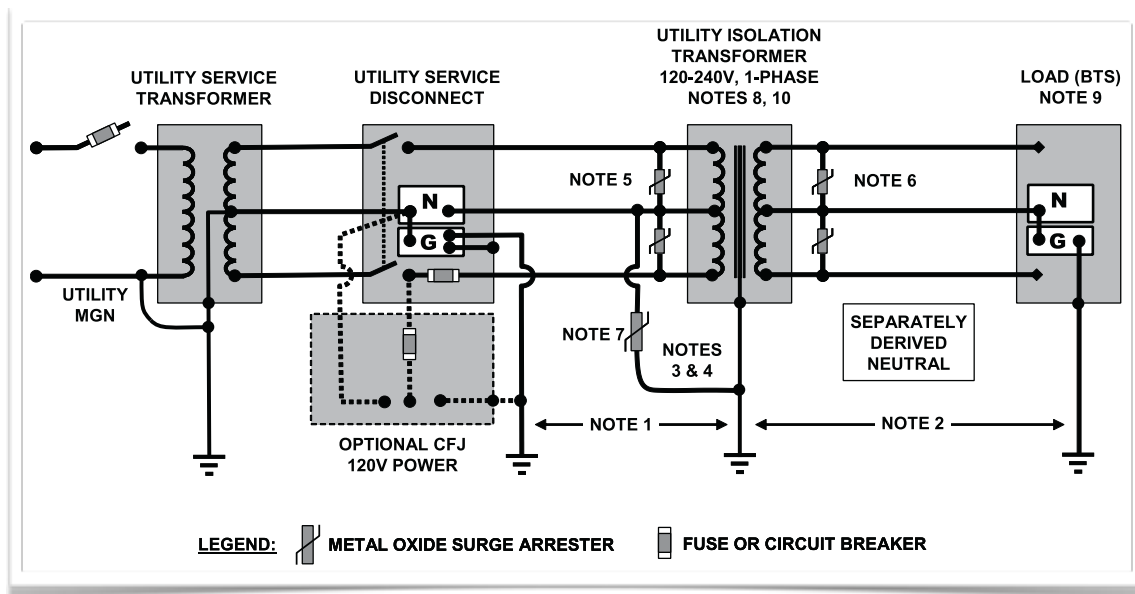


Figure 11 – Typical electrical schematic for installation of isolation transformers at wireless sites.

The following notes correspond to Figure 11.³¹

1. Isolation distance between primary and secondary grounding electrode systems should be a minimum of 50 ft. (100 ft. preferred).

³¹ IEEE Std 1590, *IEEE Recommended Practice for the Electrical Protection of Communication Facilities Serving Electric Supply Locations Using Optical Fiber Systems*

2. This distance should not exceed 30 ft.
3. The isolation transformer isolates and insulates the primary winding with neutral from the tank and secondary winding. Internal shielding between the windings is bonded to the tank.
4. At the Isolation Transformer, the tank may be ungrounded for additional isolation (NEC Article 250-110, Exception #2), but is connected to surge arresters on the load side (Low-voltage distribution Class MOV Surge Arrester, 3-pole, 175-volt). If transformer is not grounded or if metallic conduit is used Note 1 must be followed. If the transformer is not grounded then it may be grounded during work operations for added personnel safety.
5. Low-voltage Distribution Class MOV Surge Arrester, 2-pole, 175-volt.
6. Low-voltage Distribution Class MOV Surge Arrester, 2-pole, 175-volt.
7. High-voltage Station-Class Surge Arrester. Coordinate BIL protective levels needed for the Isolation transformer with over voltage capability required for isolation.
8. Ground fault indicator(s) may be required at utility service disconnecting means.
9. A Main Disconnect may be required by the NEC.
10. The isolation transformer shall have a label indicating whether it is ungrounded. The pole shall have a CAUTION note requiring a hot stick for measurements.