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IEEE Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations

IEEE Power Engineering Society

Sponsored by the
Power Systems Communications Committee

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IEEE Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations

Sponsor

Power Systems Communication Committee
of the
IEEE Power Engineering Society

Approved 12 December 2003

IEEE-SA Standards Board

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Abstract: The main emphasis of this recommended practice is the engineering design of optical fiber communication facilities serving, or connected to, electrical supply locations. This document includes methods for providing telecommunication facilities serving electrical supply locations using optical fiber cables extending across the zone of influence (ZOI).
Keywords: electrical power stations, electrical supply locations, ground potential rise, high-voltage environment

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Introduction

(This introduction is not part of IEEE Std 1590-2003, IEEE Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations.)

Some electrical environments, collectively called electrical supply locations, require the application of unique electrical protection techniques because of their special nature. One such environment is the electrical power station or substation. Another is at, or near, power line transmission and distribution structures such as towers or poles. Such structures often provide a convenient site for the location of wireless, PCS, and cellular antennas and their associated electronic equipment that is served by a link to the wired telecommunications network. IEEE Std 487™-2000 provides additional details on these locations.

This recommended practice assumes that optical fiber cables are to be used to provide telecommunications services to electrical supply locations. Refer to IEEE Std 367™-1996 or IEEE Std 487-2000.

This document describes applications consisting entirely of fiber and of those hybrid applications where both metallic cables and fiber cables are used. In this instance, the user will be referred to IEEE Std 487-2000 for the metallic portion of the application.

Delays in site activation often occur due to the time involved in obtaining electrical information data for most high-voltage tower or pole sites. The delays may be eliminated by using the fiber optical solutions described in this recommended practice.

This recommended practice has been prepared by the Wire-Line Subcommittee of the Power Systems Communications Committee of the IEEE Power Engineering Society. This standard represents the consensus of both power and communications engineers.

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IEEE Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations

1. Overview

During a power fault that occurs externally to the electrical power station, some portion of the fault current will return to the electrical power station through the resistance of the station grounding system. A large increase in potential may be developed in and around an electrical power station (ground potential rise zone of influence) with respect to remote earth locations. This ground potential rise (GPR) will result in current flowing into the wire line networks or the power system neutral.

When a fault occurs on the power line transmission and distribution towers or poles, the current will return to the source via the earth and the various metallic paths available. The fault current will divide following the paths of least impedance. Some power systems have a neutral return path, and others do not. The absence of the neutral return path tends to produce a higher GPR. When wire line telephone and secondary neutrals are extended into these locations (no neutral return path), they represent remote earth and provide a significant discharge path during faults. A properly engineered and deployed all-dielectric fiber optic cable will provide immunity from the effects of fault-produced GPR and induction at these locations. Guidance is provided for existing nondielectric fiber optic cables.

The main emphasis of this recommended practice is the electrical protection of optical fiber communication facilities serving, or connected to, electrical supply locations. The overall electrical protection scheme for the particular location should be coordinated for personnel safety and to minimize damages to equipment and service outages.

This document includes methods for providing telecommunication facilities serving electrical supply locations using optical fiber cables extending across the zone of influence (ZOI).

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1.1 Scope

This recommended practice presents engineering design procedures for the electrical protection of optical fiber communications facilities serving, or connected to, electrical supply locations. Other telecommunication alternatives such as radio and cables with metallic members are excluded from this document.

1.2 Purpose

This recommended practice presents safe and reliable methods for providing telecommunication facilities serving electrical supply locations using optical fiber.

1.3 Not covered

This document does not cover fiber extension where the equipment (CFJ) is inside the ZOI or where the equipment (CFJ) is on the same grid or ground mat. These are covered in IEEE Std 487™-2000.[1]

2. References

This recommended practice shall be used in conjunction with the following publications. When the following specifications are superseded by an approved revision, the revision shall apply:

Accredited Standards Committee C2-2002, National Electrical Safety Code® (NESC®).[2]

IEEE Std 80™-2000, IEEE Guide for Safety in AC Substation Grounding.[3, 4]

IEEE Std 367™-1996 (Reaff 2002), IEEE Recommended Practice for Determining the Electrical Supply Location Ground Potential Rise and Induced Voltage from a Power Fault.

IEEE Std 487-2000, IEEE Recommended Practice for the Protection of Wireline Communication Facilities Serving Electric Supply Locations.

NFPA 70-2002, National Electrical Code® (NEC®).[5]

3. Definitions

For the purposes of this recommended practice, the following terms and definitions apply. *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition [B10] should be referenced for terms not defined in this clause.

3.1 base transceiver station (BTS): A unit or component of the cell site consisting of all radio transmission and receiving equipment.

[1]Information on references can be found in Clause 2.

[2]The NESC is available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

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3.2 electrical power station: A substation or generating station.

3.3 electrical supply locations: Any building, separate space, or site in which electrical supply equipment is located that may be subjected to the effects of ground potential rise (GPR) from power system fault currents. This includes generation, transformation, conversion, switching, and delivery facilities.

3.4 ground potential rise (GPR): The product of a ground electrode impedance, referenced to remote earth, and the current that flows through that electrode impedance.

3.5 high-voltage environment (HVE): A location requiring caution because it may experience a ground potential rise (GPR) from power line fault currents and/or lightning strike energy.

3.6 high-voltage interface (HVI): Protective apparatus that provides electrical isolation of wireline communications conductive paths.

3.7 metallic member: A noncommunications metallic cable component such as a shield, vapor barrier, or strength member.

3.8 outside plant: That portion of the telephone network that is normally located outside of buildings. It may consist of aerial, buried or underground facilities and associated terminals, closures, pedestals and supporting structures.

NOTE— See T1.316-1997 [B20].[6]

3.9 optical equipment interface (OEI): Interface between the optical fiber cable facility and the metallic cable for the base transceiver station (BTS).

3.10 personal communications service (PCS): A set of capabilities that allows some combination of terminal mobility, personal mobility, and service profile management.

3.11 wireless: For the purposes of this document, a form of telecommunications using radio links to deliver voice, data, and other information.

3.12 wireless services provider (WSP): A company that provides wireless telecommunication service to customers, e.g., cellular service providers, radio common carriers, and paging companies.

3.13 wireline: A term associated with a network that uses metallic wire conductors for telecommunications.

3.14 zone of influence (ZOI): An area around a ground electrode bounded by points of specified equal potential resulting from the voltage drop through the earth between the ground electrode and remote earth.

4. Abbreviations and acronyms

ac	alternating current
ANS	American National Standard
AWG	American Wire Gauge
BIL	basic impulse insulation level
BTS	base transceiver station
CFJ	wireline cable— fiber cable junction
CO	central office
dc	direct current

[6]The numbers in brackets correspond to those of the bibliography in Annex A.

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FCC Federal Communications Commission
GPR ground potential rise
HVE high-voltage environment
HVI high-voltage interface
LEC local exchange carrier
MGN multigrounded neutral
MGNV multigrounded neutral vertical
MPE maximum permissible exposure
NEC National Electrical Code
NESC National Electrical Safety Code
OEI optical equipment interface
OGC overhead ground conductor
OGW overhead ground wire
OPGW optical ground wire
PCS personal communications service
RF radio frequency
SPO service performance objective
WSP wireless service provider
ZOI zone of influence

5. Overview of telecommunications service to electrical supply locations

Telecommunications service to electrical supply locations is provided via a link that connects the telecommunications equipment located at, or near, the electrical supply location with the central office or switching center of the telecommunications service provider. Although telecommunications services to an electrical power station include a large variety of types (see Annex B), telecommunication services to a wireless cell site are usually DS-1 or DS-3 type circuits.

The telecommunications facility may be either a metallic wire line cable, an optical fiber cable, or a microwave system.

Wireless cell sites are established at a variety of locations, including some at, or near, power line transmission and distribution structures such as towers or poles. These locations typically have a telecommunications facility that connects the associated electronic equipment, or BTS, with the wireless switching center, either directly or through a telecommunications central office (see Ashdown et al. [B1] and Bellarmine and Lee [B2]).

5.1 Service via metallic wireline facilities

When the telecommunications facility consists solely of a metallic wireline cable, then IEEE Std 487-2000 is used to determine the level of electrical protection needed at the electrical supply location.

5.2 Service via fiber optic facilities

The use of a fiber optical system to serve an electrical supply location should be considered when the bandwidth requirements of wireline facilities are exceeded. In addition, the fault producing the GPR and induction at the electrical supply location may exceed the capability of the metallic wireline facility. In an electrical supply location environment, a fiber optical system may be viewed as both a communications transport medium and isolation protection, assuming proper methods for metallic facilities are deployed.

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5.3 Wireless sites owners' responsibilities

All wireless installations shall comply, at a minimum, with NEC and NESC requirements to ensure personnel safety in all aspects of the installation.

NOTE—Canadian Electrical Code Parts I, II, and III, or other applicable local codes may also be applicable.

The owner shall also ensure that NESC requirements are met with respect to access, approach distances, and qualified personnel around energized facilities.

The owner of the tower and/or pole shall accept responsibility for the overall coordination of work to be done on, or at, their site. At electrical supply locations (power stations and power line transmission and distribution structures such as towers or poles), the owner shall provide the expected GPR, the electrical characteristics for determining touch, and step potential information.

All work off the ground on the power line towers or poles, including placing and routine maintenance operations, shall be performed by qualified or licensed personnel.

6. Powering arrangements at electrical supply locations

Electrical supply locations have a variety of powering arrangements. Electrical power locations typically have local power systems, either ac or dc, for the equipment located within the site. For reliability purposes, the local power is usually backed-up. Power sources at, or near, power line towers or poles need special considerations (see 6.3).

6.1 Typical ac power service to wireless locations at power line towers or poles

The commercial power to a wireless site is often a single-phase 120/240 V secondary service with the center-tapped neutral bonded to the primary MGN at the distribution transformer and grounded at the wireless site. This secondary neutral provides a path for the transfer of high potential during line-to-ground faults at a tower. Studies (van Waes et al. [B21], [B22]) have shown that when OGW (static or lightning wires) are employed, the distribution low-voltage conductors may carry one-third of the current back to the source transformer. Without overhead grounding conductors, they are the primary discharge path.

6.2 Distribution transformers

The enclosures housing the electronic equipment require ac power that is typically provided through a distribution transformer. If a flashover occurs on the high-voltage system, the resulting fault current may travel to the distribution neutral conductor. If the fault current is of sufficient magnitude and the neutrals are not properly isolated, serious damages could occur to homes or businesses in the neighborhood (down the line from the distribution transformer). As the distribution transformers often feed adjacent customers, they may become a part of the return circuit.

Distribution transformers located in close proximity to high-voltage transmission towers and used to provide ac power to an electronic equipment enclosure (also located in close proximity to high-voltage transmission towers) shall have the neutrals separated by a spark gap or similar device. Alternatively, a separate and dedicated distribution transformer shall be used to provide power solely to the electronic equipment enclosure. This transformer (associated with the tower and BTS enclosure) shall not be used to provide ac power to either residential or commercial structures nearby, but they could be used to provide power to several enclosures of different WSPs, provided that they are bonded together (see van Waes et al. [B21], [B22], and [B23]).

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Several power companies require special grounding and the placement of pole-mounted isolation transformers in series with the commercial power to mitigate the hazard (see Rajotte et al. [B19]). The Y grounded distribution system is stepped down from the primary voltage to 120 V ac and then transmitted in an ungrounded configuration to a 120 V grounded isolation transformer with a BIL of 100 000 V or greater (see Figure 1). This design allows the wireless equipment to have a neutral grounded electrical system that will provide a return path to the low-voltage isolation transformer. This provides safe operation on their ground grid and isolation for the high-voltage return current associated with a line-to-ground fault of the transmission voltage.

6.3 Electric field induction

Ungrounded telecommunications cables and hardware, as well as personnel, located in the vicinity of high-voltage power transmission lines may become electrically energized by electrostatic coupling to the high-voltage power line. An ungrounded object, including a person, will assume a potential relative to the earth, based on the power line voltage and geometry, and the capacitance of the object or person with respect to both the power line and the earth (see T1.316-1997 [B20]).

Personnel working near high-voltage lines may become charged by the electric field surrounding the lines. The voltages can be large, and the available current is usually small, below the level that may cause electrical injury. The electric shock or arc obtained may be startling, causing accidental injury as a result of involuntary reaction.

Grounding of telecommunications plant and hardware helps to minimize the possibility for injury because of involuntary reactions by keeping the cables and hardware and the earth near them at the same potential.

6.4 Emergency engine generating units

The emergency engine generator shall be installed in accordance with the requirements of the NEC for a separately derived system.

Engine generators shall be used to provide ac power only on a temporary basis (less than 45 days) while waiting for permanent utility ac power or until service is restored after a service outage.

Temporary installations shall comply with the following restrictions:

— The engine generator and any separate aboveground metallic fuel storage container shall be effectively bonded to the site's grounding system.

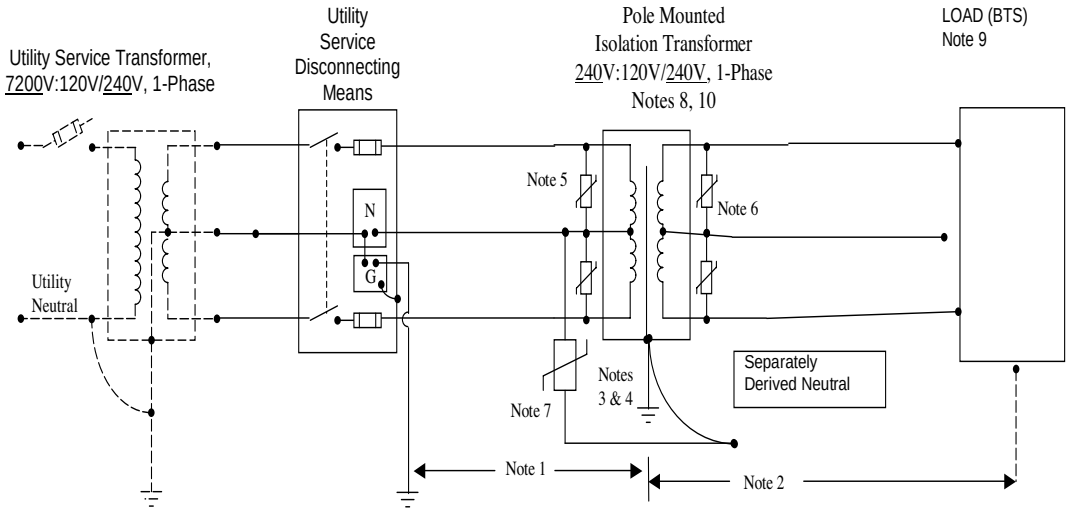
— Buried grounding rings or temporary grounding mats shall be installed around the engine generator and any metallic fuel storage container.

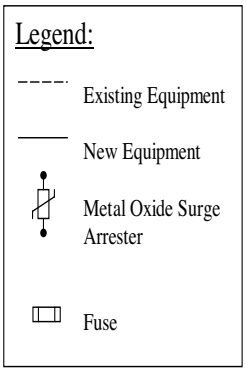
Whenever practical, refuel equipment off the power line easement or fee-owned property to eliminate arcing. When not practical, transfer flammable liquids between metal containers only after electrically bonding the containers together to eliminate the potential for arcing ignition of the fuel.

7. Telecommunications service to electrical supply locations

Most electrical power stations receive telecommunications services via metallic wireline facilities (metallic twisted-pair cables). IEEE Std 487-2000 is used to determine the level of electrical protection needed at the electrical power station. Technology has been moving from metallic wireline facilities to optical fiber cable. When optical fiber cables are used across the ZOI to provide telecommunication services to electrical power stations, this recommended practice should be used.

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NOTES

1—Isolation distance between primary and secondary grounding electrode systems, minimum 15 m (30 m preferred).

2—This distance should not exceed 9 m.

3—The isolation transformer uses oil-paper insulation, with high-voltage insulation isolating and insulating 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 (NFPA 70-2002 Article 250-110, Exception #2), but it is connected to surge arresters on the load-side (low-voltage distribution class MOV surge arrester, 3-pole, 175 V). If the 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 V.

6—Low-voltage distribution class MOV surge arrester, 2-pole, 175 V.

7—High-voltage station-class surge arrester. Coordinate BIL protective levels needed for the isolation transformer with overvoltage 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.

Figure 1—Typical electrical schematic for installation of isolation transformers at tower/poles structures for wireless sites

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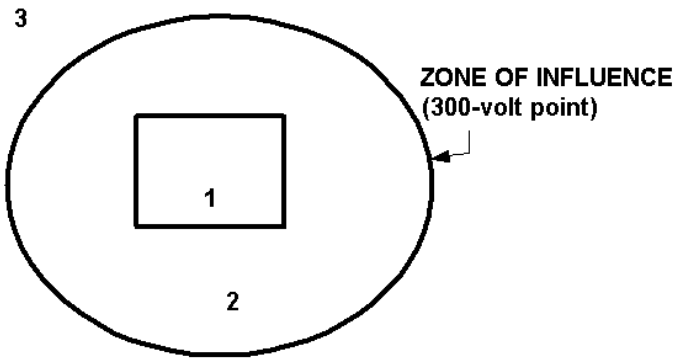
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Recently, the use of optical fiber cables to provide these services has started. This recommended practice should be used to determine the level of electrical protection needed at the electrical power station when using optical fiber cables. At large electrical power stations, protection measures for wireline facilities traversing the station are covered in IEEE Std 487-2000.

7.1 Wireless sites at electrical supply locations

Wireless sites built inside or attached to the grounded fences of electrical power stations (location 1 in Figure 2) can be protected using the standards recommended in IEEE Std 487-2000 when metallic wireline facilities are used.

High-voltage isolation systems, such as those used at electrical power stations, may be used to effectively protect metallic telecommunications plant at high-voltage tower and pole sites. However, because the GPR at a high-voltage tower or pole can be significantly higher than at an electrical power station, the isolation capability of the high-voltage isolation equipment and/or the isolation capability of the metallic telecommunications plant may be exceeded (see T1.316-1997 [B20]). Prior to implementing a high-voltage isolation system at a high-voltage tower or pole site, the maximum expected site fault-produced GPR shall be determined. An analysis of GPR calculations is presented in IEEE Std 367-1996. Information concerning the application of high-voltage isolation systems for metallic facilities is contained in IEEE Std 487-2000.



NOTE—1, 2, and 3 are locations referred to in the text.

Figure 2—Locations at, or near, high-voltage towers or poles

The 300 V point is where the general-cable may fail in the pair-to-pair and pair-to-shield modes at the splices. Similarly, some 3 mil carbon blocks may fire as low as 300 V peak. When determining the peak value of voltage in meeting this criteria, adding an appropriate value of dc offset of the transient voltage to the steady-state GPR (expressed in V peak) is necessary.

Note—Many administrations have chosen a value of 300 V, either rms or peak, as the upper voltage limit. Other administrations have chosen values such as 420, 430, or 650 V rms or peak. Some administrations have chosen even higher voltages on the basis of their higher cable and equipment dielectric withstand capabilities.

7.2 Wireless sites within the zone of influence

Wireless sites that are located in close proximity of an electrical supply location subject to GPR may require special protection. The requirements of the electronics equipment (BTS) manufactures usually require an earth reference of less than 5 ohms to ensure good grounding to dissipate lightning strikes. This earth reference offers a path for fault current during a fault-produced GPR event. When the fault-produced GPR event causes the earth to rise relative to remote earth, the transfer of potential will cause the current to flow through the low-impedance ground grid of the wireless sites and drain through the remote grounded metallic

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paths such as the telephone cable and power neutral. The current may produce voltages that may require special high-voltage protection on any wireline or metallic communication cable interface.

7.3 Locations at, or near, high-voltage towers or poles

Telecommunications outside plant serving equipment at, or near, power line high-voltage towers or poles is subject to GPR. Although the probability of a severe fault-produced GPR occurrence at a particular power line tower or pole is lower than that for a similar occurrence at an electrical power station, the fault-produced GPR magnitude can be significantly greater because of higher grounding resistance. Grounding at high-voltage towers and poles is usually accomplished through the use of ground rods, counterpoise conductors, and overhead grounding conductors. This typically results in a greater resistance to earth than is achieved through the use of the large-area grounding grids or mats employed at electrical power stations. Unless special protection measures are employed, a fault on the transmission and distribution systems can introduce large currents into the telecommunications plant resulting in service outages and possible plant damage.

7.4 Electrical protection considerations for telecommunications outside plant serving high-voltage tower and pole sites

Telecommunications outside plant serving high-voltage and pole sites requires special electrical protection considerations because of the large currents and fault-produced GPR that can occur at these locations during lightning and power fault events. The fault current and GPR can damage not only the telecommunications outside plant serving the location, but also the BTS equipment being served. Equipment damage can occur when the wire line telecommunications outside plant presents an electrical connection to remote earth, permitting the full fault-produced GPR to appear across the equipment between its local ground connection and its telecommunications ports connecting to the wire line telecommunications network. The mitigation of outside plant and equipment damage from high-voltage transmission line faults should be a primary objective, and electrical protection measures should be implemented.

7.5 Electrical protection measures

7.5.1 All-dielectric optical fiber cable

Effective electrical protection of the telecommunications outside plant may be accomplished by using an all-dielectric optical fiber cable to serve electrical supply locations.

Serving the BTS equipment at a high-voltage tower or pole site using an all-dielectric optical fiber cable, from an electrical protection perspective, provides the simplest and most reliable solution to a complex problem. Service can be provided using an optical fiber cable from the central office to the site (see Figure 3), or alternatively, by using a shorter optical fiber cable from the CFJ to the site (see Figure 4). The CFJ should be located at a safe distance from the tower or pole (see Clause 10).

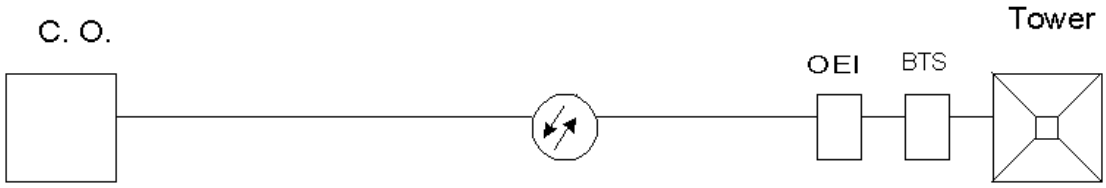


Figure 3—Typical solution using optical fiber cables

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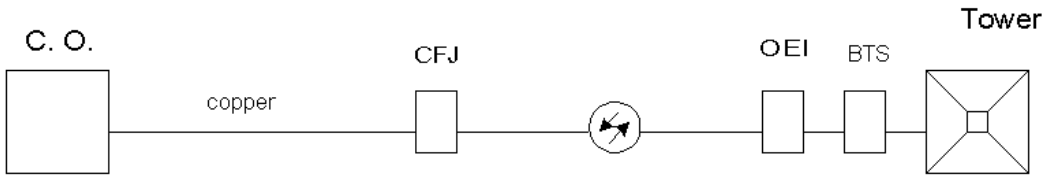


Figure 4—Typical hybrid solution

7.5.2 Optical fiber cable with metallic members

When the use of optical fiber cables with metallic members cannot be avoided, such as when using an OPGW, then a transition point should be established. The transition point is usually accomplished by splicing within a closure. At this point, the metallic members are stopped and an all-dielectric optical fiber cable starts. The transition splice point should be 30 m away from the equipment,[7] especially when the cable is below surface or in conduit. For aerial installations, such as OPGW or cables with metallic members, the distance between the transition splice and the equipment should allow a *minimum* of 3 m of all-dielectric optical fiber cable.[8]

7.6 Typical grounding

7.6.1 Electrical power stations

The design of grounding electrode systems for electrical power stations is a complex subject, beyond the scope of this document. See Del Alamo [B6], Pham [B16], and IEEE Std 80-2000 for information.

7.6.2 Typical grounding at power line structures such as towers or poles

Traditional lattice towers consist of four-legged structures ranging from 3 by 4.5 m to[9] 12 by 12 m spacing[10] between the legs. Their grid impedance is recommended by the NESC to be less than 25 ohms (measured per IEEE Std 81™-1983 [B8] or IEEE Std 81.2™-1991 [B9]). In conductive soils with high water table, 0.5 ohms is possible without augmenting the grounding systems. In poor soils, such as crystalline granite or basalt, the grid impedance may exceed 200 ohms.

Many towers have ground rods driven at all four corners and ground rings or counterpoise grounds to lower their earth resistance. When wireless sites are located underneath a tower, their ground grid may augment the existing tower grounding and reduce the grid impedance. When the wireless site grid is built off to the side of the tower, and bonded to the tower, the grid impedance will be reduced and may approach the characteristics of a small substation. If additional wireless providers colocate and change the parameters of the grid, a review of the electrical characteristics will be required to ensure a safe and reliable design.

Single metallic monopoles typically have less than 1 m^2 earth contact and rely on their concrete and steel foundation for an earth reference.[11] These sites will rarely obtain 25 ohms or less. The wireless ground grid is built off to the side and significantly increases the earth electrodes, lowering the grid impedance.

[7] 100 ft.
[8] 10 ft.
[9] 10 by 15 ft.
[10] 40 by 40 ft.
[11] 10 ft^2.

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Wooden “H” fixtures and single monopole leads sometimes have no earth reference in low lightning areas. Because they are ungrounded or source-grounded systems, they rely on their vertical clearance and the resistance of the wooden structure to insulate or isolate from ground. A fault on these structures can be very violent and have extended clearing times. When wireless sites are attached to these structures, they introduce a grounded system into an ungrounded environment. This may cause severe damage to the grounded system and all remote grounded conductors during fault conditions.

Wooden poles with multigrounded (Y) distribution under builds provide multiple discharge paths for fault current and will reduce the earth current through the grid that causes GPR. The NESC requires these systems to be bonded to the MGNV on the joint use structures and to maintain vertical and horizontal clearances, to assure personnel safety while working on the pole. If the grounded coaxial or other conductors extend up through or above the ungrounded phase conductors, they must meet Rule 239 of the NESC. A fault of the ungrounded system may distribute fault currents over the neutral distributions network and other grounded conductors, thereby reducing the earth return current through the wireless site’s grid. Significant damage to the equipment and other structures in the immediate vicinity may occur, until the current drops below dangerous levels. This is particularly a problem in rural areas with few ground references or rocky and high-resistant soils.

Throughout areas subject to lightning, many power companies employ overhead grounding systems: OPGW (IEEE Std 1138™-1994 [B12]), OGW, OGC, sky wires, or static wires. These OGW provide protection to the transmission systems by providing a shield above the phase wires that directs the lightning to ground. These overhead grounding systems may be tied together from tower to tower to provide multiple discharge paths. The impedance of the OGW will reduce the current at each subsequent tower until the lightning is discharged. During a line-to-ground fault or follow-through fault, the line current will be distributed along multiple discharge or power follow current paths; this OGW will reduce ground return current at individual towers and reduce clearing time of the fault, by providing a more direct path to operate relays. These systems follow many different protection designs from being grounded at each tower and the substations, to being insulated with a 3–5 kV spark gap device at every tower or every fourth tower. They may be stopped two to four spans before the substation or extend from the substation three to four spans only to protect the substation alone. In low lightning areas, they may not exist at all, leaving each tower to stand on its own. The net affect of the OGW is to reduce the ground return current at individual towers by providing multiple discharge paths. This in turn reduces the current flowing through the ground grid, reducing clearing time and lowering fault-produced GPR to manageable levels.

7.6.3 Typical grounding requirements for the BTS

Several documents, such as R56 [B18], are in general use in the wireless industry. These documents provide minimum grounding requirements, along with site preparation recommendations, necessary to meet warranty conditions from equipment vendors or manufacturers. These documents tend to recommend low ground resistance at the sites. When the sites are located at, or near, power line transmission and distribution structures such as towers or poles, enhancements of the ground field may be necessary to meet these requirements.

8. Telecommunications service to electrical supply locations—recommendations

The use of all-dielectric optical fiber cables is a solution to some of the problems of providing protection at electrical supply locations.

Special protection considerations pertaining to fiber optical systems serving electrical supply locations are primarily a function of the presence or absence of metallic members in the fiber optic cable, conduits, or

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locating systems. The use of all-dielectric optical fiber cable provides immunity from the effects of fault-produced GPR and induction at the electrical supply location.

The use of optical fiber cable containing metallic strength members, a metallic foil vapor barrier, or talk pairs is not recommended, within the zone of influence, because it raises protection considerations:

— GPR related

— Induction related

8.1 GPR-related protection considerations

In the case where a fiber optic cable is employed between the electrical supply location and the edge of the zone of influence, the metallic elements of the cable must be isolated from the electrical supply location ground and grounds within the zone of influence. This isolation is necessary to prevent the fault-produced GPR from being introduced directly onto the metallic components. An intentional low-impedance ground connection to the metallic components will allow potentially damaging currents to flow on the cable from the grounded point to remote earth at times of power faults. As the fiber optic cable must traverse the GPR zone of influence, it must have sufficient dielectric strength in its outer jacket to preclude any breakdown between earth (or a grounded support strand in aerial construction) and its inner metallic components.

8.2 Induction-related protection considerations

When the metallic members are isolated from ground, induced voltages will be developed on the metallic members and will appear between the metallic members and ground. If all metallic elements in the cable are isolated, all will have the same voltage induced on them and there will be no stress between metallic members in the cable. There will be stress between the metallic components and ground. Therefore, the dielectric strength of the cable's outer insulating jacket must also be sufficient to withstand the expected fault-produced longitudinal induction. Where both electrical supply location fault-produced GPR and induction in the zone of influence are present; the vector sum of the two voltages will be at a maximum at the electrical supply location and will appear between the ground grid and cable. The most critical need for isolation, therefore, is at the electrical supply location proper and in the nearby zone of influence.

8.3 Benefits of all-dielectric cables

When the all-dielectric fiber optic cables are used to serve these electrical supply locations, they will have a nonmetallic strength support member (i.e., nylon, fiberglass, or equivalent) and shall not contain any metallic pairs, which will also be immune to the fault-produced GPR and induction. It is critical that appropriate support hardware be employed to maintain the cables' all-dielectric properties. It is recommended that the last section from at least 30 m outside the fall line of the phase wires on transmission towers and all parallel runs within the transmission corridor be underground in PVC conduit.[12] If metallic support strands are used or the fiber optic cable is lashed to existing cables, care must be taken to avoid grounding the strand or anchors within 6 m (see NESC 215C2, 215C3, and 279) of the electrical supply location ground grid. The use of a strand insulator with adequate voltage rating is encouraged.

9. Construction concerns and general recommendations

a) The optical fiber cable(s) shall be fully dielectric. The cable(s) shall not contain metallic members, including copper pairs.

[12] 100 ft.

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b) There shall not be any metallic wires placed along or near the optical fiber cable(s). Locating should be done with electronic (frequency-based) devices or passive reflectors external to the optical fiber cables.

c) The optical fiber cable shall be in conduit (PVC Schedule 80 minimum). The conduit shall extend to the edge of the public right-of-way or easement.

d) At any one site, all enclosures housing the wireless electronic equipment shall be on the same grounding grid.

e) When the sites are fenced, the fences shall be grounded as required by the NESC.

f) Sites should be set up with crushed stone, or gravel, to minimize step potential. See IEEE Std 80-2000 for guidance.

Underground cables shall not cross transmission line grounding systems and shall maintain a minimum clearance of 6 m from the end of a grounding system to prevent disturbing the site's ground field.[13]

9.1 Existing facilities

Metallic messengers shall be grounded at the edge of the ZOI and should be isolated throughout from the ZOI to the electric supply location.

Locating/tracing wires are to be interrupted for 3 m as often as needed within the ZOI to make it a safe installation.[14]

10. Location of the CFJ

As the CFJ has electronic equipment, the location must be accessible to personnel and provide a reasonably safe environment for working. Gas tube protection should be placed from pairs to shield to protect the electronic equipment from induced voltage and fault-produced GPR and the shield grounded at that location. The cable shield should be electrically continuous from the CFJ back to the central office.

The safety concern is the touch potential from a power line GPR. The probability of a person having contact with the earth and a cable pair or shield at the exact time of a fault-produced GPR is extremely low. Workers are cautioned to avoid working around towers during thunderstorms when the probability of a power fault is higher.

For fiber optic cable or metallic digital carrier facilities between the CFJ and the CO (see Figure 4), normal grounding practices should be applied. The metallic facilities between the central office and the CFJ should be protected in accordance with the requirements for the appropriate service types and SPO described in Annex B. See IEEE Std 487-2000 for specific details.

At the CFJ, the fiber cable from the OEI could be terminated in another optical-electrical signal conversion terminal that, in turn, is connected to a digital carrier system operating on metallic facilities back to the CO. Alternatively, the fiber cable from the OEI could be routed the entire distance to the CO without connection to a digital carrier system.

Regardless of the design and make-up of the facilities, it is important that equipment such as carrier terminals, optical-electrical conversion terminals, and repeaters or regenerators not be located within the GPR zone of influence. As with other protected apparatus, there is the risk of protector operations and service

[13] 20 ft.
[14] 10 ft.

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interruptions due to GPR during power faults conditions. Induced voltages into a wireline cable from any paralleling power line fault current may also cause protector operations and service interruptions.

10.1 Electrical power station

The CFJs should be located at the remote drainage location or at the edge of the zone of influence based on fault-produced GPR calculations.

10.2 Wireless sites

It is recommended that CFJs should be located outside of the ZOI. A ring of bare copper wire 0.3 m in the soil encircling the CFJ and bonded to the cable shield ground will greatly reduce the touch potential.[15] The reason for the ring is to provide an equipotential surface for those instances where clearing time is long. Working on an insulated blanket at this location would eliminate the touch potential concern.

NOTE—In the absence of GPR data, the CFJ may be located at a minimum of 150 m from the tower.[16] A total of 150 m assumes a 150 m^2 grid (or ground mat) and safe touch potentials.[17]

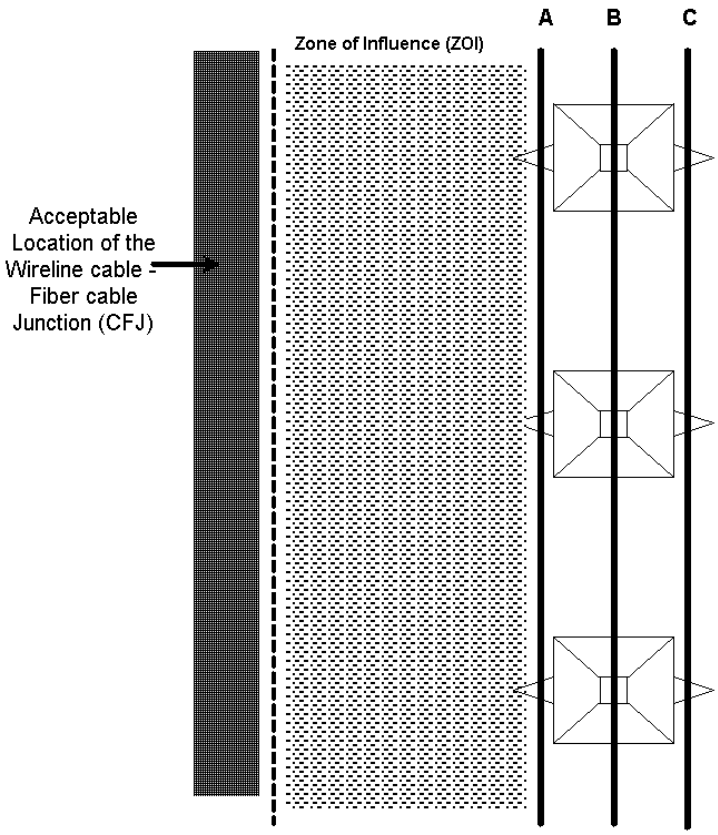


Figure 5—Location of the CFJ for high-voltage towers or poles sites not associated with electric power stations.

[15] 12 inches.
[16] 500 ft.
[17] 1600 ft^2.

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11. Typical dc powering arrangements

These considerations pertain to the OEI and the CFJ.

The powering of optical fiber communications facilities requires two separate sources. As the optical system relies on fiber to pass the communications signal, they are only as reliable as the electrical systems providing the power to their active components.

11.1 CFJ

The CFJ, at the end of the metallic pairs, is typically powered by an isolated source such as CO line power. If the CFJ is in the CO, or at a loop electronics extension such as a fiber hut, it is assumed to be located outside the ZOI of the electrical supply location. If it is within the ZOI, it may be subject to service interruption due to power induction or GPR during a fault. The CFJ shall not be directly powered from the electrical supply location's ac power.

Some backup source, such as a battery system, should be used to ensure power reliability.

11.2 Remote end and the OEI

The OEI, where signal conversion occurs (electrical to optical and vice versa), should be powered from a reliable local source.

The remote end should have a local power source such as a station battery. It is recommended that the same backup power be provided to the OEI and the BTS to avoid separate power systems failing at different times. This will also eliminate maintaining duplicate facilities. This requires that voltage, current and polarity requirements be coordinated. It should be noted that the BTS equipment normally operates at positive 24 V dc, but other voltages may be used.

12. Installation and inspection considerations

12.1 Installation considerations

The equipment enclosure located at the cell site (BTS) should be connected to the site grounding system. A bare copper ground ring, minimum of 2 AWG solid bare tinned copper conductor, should be buried around the equipment mounting pad to reduce hazardous touch and step potentials. The equipment mounting pad should be located at least 2.5 meters[18] from the fence unless that section of the fence is bonded to the site's ground grid.

Safe limits for potential differences during fault conditions, including step and touch potentials, are described in IEEE Std 80-2000. These methods should be applied to wireless sites at electrical supply locations. The grounding requirements for these wireless sites should be equivalent to the electrical power station locations to ensure minimal differences in potential.

[18] 8.2 ft.

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12.2 Periodic considerations

Periodic, usually annual, detailed inspections by all companies (power utility, telephone, and wireless) of all aspects of protection facilities in and around the high voltage site are necessary to ensure that special protection requirements have not been violated or negated.

As a protection system is quiescent, many such defects will not become apparent until the protection system fails to function properly under fault conditions, causing failure or damage, or both, to critical equipment, and, possibly, injury or loss of life.

All companies should work out the frequency within which such inspection should be conducted. In addition to planned, periodic tests, this practice recommends that a very thorough inspection of the protection facilities, including bonding and grounding, be made following each case of faulty or questionable operation of such facilities, particularly if damage has resulted.

13. Safety

13.1 General safety considerations

The basic safety objective (see Poulin [B17]) is to protect personnel from coming into contact with both remote and local grounds simultaneously. Therefore, safety consideration shall be directed toward the following goals:

a) Educating personnel regarding the special hazards of working on communication facilities located at electrical supply locations.

b) Minimizing the possibility of simultaneous contact with both remote and local grounds.

c) Reducing the length of time that personnel spend working at the site under conditions that may expose them to danger.

13.2 Electrical safety

Technicians assigned to work in cell sites at or near electrical supply locations and/or at the CFJ shall be made aware of proper safety techniques.

Work shall not be performed on communication circuits when electrical storms are occurring in the area through which the circuits pass. Furthermore, work should not be performed on equipment that has become wet from rain or other causes.

Safety precautions are required for ALL work with conductive facilities, such as metallic telephone conductors, metallic cable shields and armors, metallic messengers, remotely grounded metallic structures, and the like.

Observe the following safety precautions:

— Always contact the WSP representative before performing any work inside the cell site.

— Use a rubber blanket, (and/or insulated footwear) and rubber gloves of at least 20 kV dielectric strength rating (Class 2).

— Isolate parts of the body from contacting the earth, grounded conductors, or any extensions of earth (local ground).

— Avoid touching or stepping between the remote grounded facilities and local ground or locally grounded facilities such as earth, walls, and fences.

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Different administrations may implement stricter safety precautions, detailed in applicable safety practices, for installing or maintaining protective devices or placing cables within the GPR zone of influence.

13.3 Radio frequency safety awareness

ALL individuals that might work in cell sites shall have received training on RF awareness as required by FCC regulations (Bulletin 65 [B3]).

In 1996, the FCC adopted regulations setting forth RF exposure limits for cell sites.[19] These guidelines apply to operations in the frequency range of 300 kHz to 100 GHz. The MPE for personnel varies depending on frequency. The MPE levels are conservative and have been set to provide substantial safety factors for persons working near cellular transmitters.

The FCC regulations are “exposure” standards and not limits on “emissions” of RF energy. As such, compliance is designed to avoid exposure to RF for both workers and the general public that exceeds the FCC guidelines.

13.3.1 General guidelines

The following are general guidelines (see Corley [B5]) for use by all personnel (including utility line workers) working on or near antennas:

- Look for caution signs, pertaining to RF, prior to starting work.
- Assume all transmitters are energized.
- Maintain a distance of 2 m from active transmitters.[20] At a distance of 2 m, RF exposure will not exceed the MPE.
- Obey all posted signs and warnings.
- Minimize time spent in posted areas.

Do not violate the specified approach distance posted on the signs unless a personal RF monitor is worn.

[19]See Report and Order, ET Docket 93-62, FCC 96-326. See also First Memorandum Opinion and Order, ET Docket 93-62, FCC 96-487 and Second Memorandum Opinion and Order and Notice of Proposed Rulemaking, ET Docket 93-62, FCC 97-303. http://www.fcc.gov/oet/dockets/et93-62/.

[20]6 ft.

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Annex A

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[B13] IEEE Std 1222™-2003, IEEE Standard for All-Dielectric Self-supporting Fiber Optic Cable.[23]

[B14] IEEE Std 1613™-2003, IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations.

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Annex B

(informative)

Service types, reliability, service performance objective classifications, and transmission considerations [24]

The term *reliability* means different things to different people. In its broadest sense, the term *reliability* is used with the term *availability* to measure system or equipment performance over a given period of time. Reliability and availability formulae and objectives are not addressed in this document.

In the context of power system protective relaying, reliability consists of a combination of dependability and security. This subject is dealt with briefly in B.2 and B.2.1.

Service performance objective classifications, as used in this recommended practice, are a function of interruptions or outages due to the effects of power system faults (see B.2 and B.2.1).

Telecommunication services provided to electrical supply locations are of different service types and have different SPO classes in accordance with the definitions given in this annex. The responsible power utility engineer should specify the service type and the desired SPO class for each telecommunication service provided at the electrical supply location.

In addition to GPR and longitudinal induction considerations, service type, and SPO, the transmission characteristics of the channel should be considered when selecting the method of protection to be used.

B.1 Service types

For the purposes of this recommended practice, wire-line telecommunication services to electrical supply locations can be classified into four major types according to the following definitions:

NOTE—Various other classifications may be used.

a) *Type 1.* Services requiring either dc transmission or ac and dc transmission used for
   1) Basic exchange telephone service or private line, or both, voice telephone service, and so on.
   2) Teletypewriter, telemetering, supervisory control, and so on.

b) *Type 2.* Private line services requiring ac or dc transmission, or both, used for pilot wire protective relaying, or dc tripping.

c) *Type 3.* Private line services requiring only ac transmission used for telemetering, supervisory control, data, and so on.

d) *Type 4.* Private line services requiring only ac transmission used for audio tone protective relaying.

B.2 Service performance objective classifications

Interruptions or outages of wire-line telecommunication circuits serving electrical supply locations may occur for physical reasons such as cable damage due to extraordinarily heavy storm loading, a vehicle striking and breaking a utility pole, or a direct lightning stroke. Circuit failures caused by such events cannot be

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prevented but may be minimized through careful application of the appropriate construction and maintenance practices.

Interruptions or outages due to the effects of power system faults can be minimized through the installation and maintenance of special protection systems that are designed to operate in the fault-produced, electrical environment (GPR and longitudinal induction) at electrical supply locations. Because of the critical need for service continuity during power system faults on certain types of telecommunication services provided to electrical supply locations, a system of optional service performance objective classifications, for the purpose of this recommended practice, has been established for all types of telecommunication services provided to electrical supply locations. These objectives, with respect to the effects of power system faults, fall into the following three classifications:

a) *Class A*. Noninterruptible service performance (should function before, during, and after the power fault condition)

b) *Class B*. Self-restoring interruptible service performance (should function before and after the power fault condition)

c) *Class C*. Interruptible service performance (can tolerate a station visit to restore service)

B.2.1 Class A service performance objective considerations

SPO Class A is the most demanding type. Service performance for this class cannot tolerate even a momentary service interruption before, during, or after a power system fault. The nontolerable service interruptions include both loss of dependability (failure to deliver a valid trip or control signal) and loss of security (delivery of a false trip or control signal). Examples of services that may have an SPO Class A are pilot-wire protective relaying, audio-tone protective relaying, and critical supervisory (remote control) circuits.

To provide additional reliability, dual alternate routing of two SPO class A circuits should seriously be considered. This means that critical operating circuits are duplicated, end-to-end, over two geographically separated routes, minimizing the risk of simultaneous interruption of both circuits.

In addition to the special protection employed for achieving the SPO Class A, certain other special or nonstandard physical design and administrative procedures of the plant facilities should be followed. These include

a) The minimization of bridged taps and multiple appearances of these cable pairs.

b) The minimization of the number of appearances on central office main frames, with special protective covers required on all appearances.

c) These circuits should not be tested, switched, electrically contacted, or changed unless prior arrangements have been made with the appropriate group within the electric utility as to the date, time, and duration of such operations.

B.2.2 Class B service performance considerations

SPO Class B is less demanding than SPO Class A in that a service interruption can be tolerated for the duration of a power system fault, but service continuity should be restored immediately after the fault without requiring any repair personnel activity. Examples of services that are SPO Class B (with self-restoring requirements) are storm or emergency telephone circuits, telemetering and data circuits, supervisory control circuits, and signal and alarm circuits. The telecommunications engineer may determine that, for reasons of service performance, some or all, of the special, nonstandard, physical design, and administrative procedures indicated in B.2.1 described for SPO Class A are also necessary for SPO Class B.

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B.2.3 Class C service performance considerations

SPO Class C is the least demanding in that an interruption or a service outage due to a power fault that requires a station visit to restore service can be tolerated. Examples of services that are SPO Class C are basic exchange telephone service, noncritical telemetering and data circuits, and some types of signal and alarm circuits. The special nonstandard design and administrative procedures described for SPO Class A are not required to achieve SPO Class C.

B.3 Transmission considerations

The transmission characteristics of the channel should be considered in selecting the optimum protective arrangement to safeguard electrical supply location telecommunication channels.

Depending on the type of service, the transmission requirements will vary widely. For example, some services require a physical metallic pair, end-to-end. Certain channels should carry both ac and dc signals, and others are required to carry only ac signals. In the selection of protective hardware, transmission demands of the terminal equipment should be matched with the transmission capability of the channel. Transmission characteristics and SPO requirements for various types of telecommunication channels are shown in Annex D of IEEE Std 487-2000.

The following is a partial list of characteristics that should be specified by the user, if applicable, so that the transmission channel and associated protective equipment can be designed to meet the demands of the terminal equipment:

a) Type of termination (two-wire or four-wire)

b) Mode of operation (simplex, half-duplex, or full-duplex)

c) Function (remote trip, supervisory control, pilot wire, etc.)

d) Transmission (VF audio tone, dc on/off, dc pulses, etc.)

e) Attenuation requirements

f) Required frequency response

g) Steady-state noise requirements

h) Impulse noise requirements

i) Allowable harmonic distortion over frequency range of interest

j) Envelope delay distortion requirements

k) Shunt capacitance limitation between conductors of a single pair

l) Maximum loop resistance, including the neutralizing transformer (NT), if used

m) Allowable capacitive or resistive unbalance of the pairs, or both

n) Maximum differential mode voltage

o) Impedance of source and load

p) Need for metallic continuity in the channel

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Annex C

(informative)

Service request data

This annex lists some of the minimum information that should be provided by representatives of a power company or a wireless service provider to the telecommunications service provider (LEC) when requesting telecommunications services. This information is necessary so that appropriate electrical protection measures can be made to protect the technicians that use the telecommunication systems or work at the site.

The power company typically has the responsibility to characterize the environment at the electrical supply location either from their records or from measurements.

Furnishing the information in writing typically minimizes questions and delays due to misunderstandings or misinterpretations of the data. It also provides a historical trail.

C.1 Location and contact information

a) *Name*. The name of the power company or WSP should be provided.

b) *Authorized Agent*. The name, and telephone number, of the individual(s) placing the request for service should be provided.

c) *Location*. The location of the electrical supply location (either electrical power station or wireless site), where service is to be provided, should be properly identified by the use of a street address, location name, structure number, or other similar customary identification. City or town name must be given.

d) *Signatures*. The power company licensed engineer that provides the technical data should sign the form. The names, titles, and telephone numbers of the technical contact representatives (power company, WSP, and LEC) should be provided for future reference.

C.2 Circuit information

a) *Circuit Description*. Number and type of circuits desired. A projected circuit forecast may also be helpful.

b) *Service Performance Classification*. The SPO and the service type, per Annex B, should be provided for EACH circuit requested.

c) *Service Date*. The customer desired date must be provided at the time the order is placed.

C.3 Technical data

a) *Grid Area*. The dimensions of the ground mat, or grid area, should be provided in either square feet or square meters.

b) *Grid dc Resistance or Impedance at 60 Hz*. The resistance to remote earth of the ground mat at either a power substation or a tower/pole location. Provided in ohms (Ω).

c) *Expected Fault Current*. The expected total fault current (line-to-ground) at the location must be provided. Fault current is the total current produced by the fault.

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d) *X/R ratio*. This is the ratio of the inductive reactance to the resistance of the power system at the fault location. The X/R for the zero sequence component is the one usually provided.

e) *Expected GPR*. The calculated GPR information is provided as both Vrms and Vpeak.

f) *Earth Return Current*. This is the portion of the fault current that returns to the power station through the earth. Also called % earth return.

A typical sample form is shown in Figure C.1.

POWER COMPANY/WSP	AUTHORIZED AGENT	TELEPHONE:
TELEPHONE COMPANY	AUTHORIZED AGENT	TELEPHONE:
ORDER DATE:	ORDER NUMBER:	SERVICE DATE:

Circuit Number	SPO	TYPE	Circuit Description

Power Station:		Address:	
Grid Area (square feet):		Earth Return current:	
Fault Current (rms)	Grid dc Resistance or Impedance at 60 Hz (Ω)	X/R	Ground Potential Rise (GPR) rms: peak:
Pole/Tower:		Address/Number:	
Grid Area (square feet):		Earth Return current:	
Fault Current (rms)	Grid dc Resistance or Impedance at 60 Hz (Ω)	X/R	Ground Potential Rise (GPR) rms: peak:

Power Company Engineer			
Name: Title:	Telephone:	Date:	Signature:
WSP Company Engineer			
Name: Title:	Telephone:	Date:	Signature:
Telephone Company Engineer			
Name: Title:	Telephone:	Date:	Signature:

Figure C.1—Service request form

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