POSITRON INC.

toll free: (888) 577-5254

e-mail: customerservicepower@positron.qc.ca

web: www.positronpower.com

Telecommunications High Voltage Protection

APPLIED PROFESSIONAL TRAINING

toll free: (800) 431-8488

e-mail: aptc@aptc.com

web: www.aptc.com

Telecommunications High Voltage Protection

Who should be **AWARE** of the **GPR ENVIRONMENT?**

This pamphlet addresses questions of concern to anyone associated with the use of any communication signal (analog or digital) via a metallic or fiber optic cable. If you are a provider of telecommunications, electric service, wireless service or CATV, or operating in an isolated manufacturing or mining location, you may be working in a hostile electric environment. An unprotected or improperly protected system is unsafe for the public and personnel, and exposes equipment to service interruptions or permanent damage.

Whether you are new to the job or you have many years of experience, or whether you are an engineer, architect, tower erector, equipment installer, manager, tradesperson or safety supervisor, you need to know or learn:

- what your level of exposure may be,
- the protection equipment necessary for the work location,
- the necessary safety precautions,
- the accepted codes, standards and practices for addressing GPR environment issues.

The intent of this Telecommunications High Voltage Protection Booklet is to address the Who, What, Where, When, How and Why of the above issues. Should you have additional questions or need training, please contact Applied Professional Training (APT).

This generic booklet is a combined effort by APT and Positron Inc. Additional product and technical questions can be addressed to Positron's Customer Service Department.

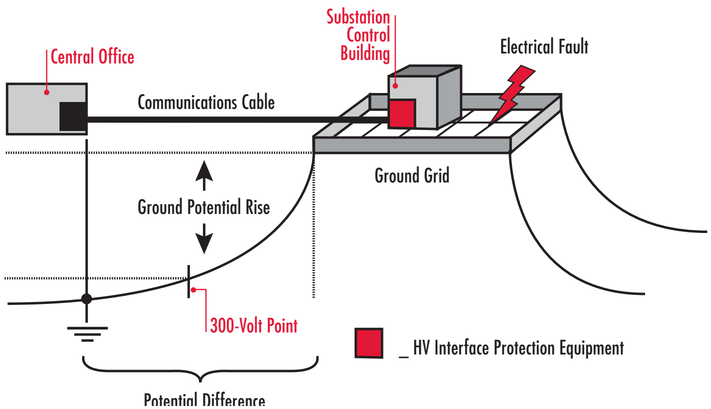
THE PROBLEM

The Basic High-Voltage Problem

When faults occur in electric power systems or when lightning strikes, a Ground Potential Rise (GPR) occurs which can damage equipment and injure personnel working on the equipment—unless proper isolation or protection is provided. The GPR produces a dangerous potential difference between the power station or PCS tower and a remote ground connection located at a central office, remote terminal, distant manufacturing building or other sites. Telecommunications cable damage can occur if grounding takes place across the potential difference caused by a power fault or lightning strike. Figure 1 shows the telecommunications equipment situation during an electrical fault condition causing GPR in the earth.

Note: Any type of cable such as twisted pair telephone cable or coax and any type of construction such as aerial, buried or underground, can experience damage. Also, any type of service can be interrupted if proper protection isn't provided.

Figure 1: Substation Ground Potential Rise



Common Questions about the HV Problem:

If you have any difficulty answering these common questions, then professional training is recommended.

1. What is GPR and why should I worry about it?
2. What is isolation?
3. What determines whether the site needs isolation equipment?
4. Why MUST ALL circuits terminated at a substation, from the same cable, be isolated?
5. How can the power system affect a communications cable when it is direct buried and/or in an underground conduit?
6. How does the isolation equipment work, and does it solve the lightning problem?
7. What could happen if isolation equipment is not provided?
8. Do I need isolation protection for DSL, POTS or any other analog or digital service?
9. Should I use different Network Channel Terminating Equipment (NCTE) at the customer or substation end than I would use at any other business customer location?
10. Does isolation lower the service capability of the circuits?

Engineering, GPR calculations and PROTECTION EQUIPMENT

In general, special protection equipment, corporate policies and procedures are necessary to ensure the safety of personnel and protection of equipment (including cables, termination equipment, etc.). The reliability of communications circuits is questionable when they are in an unprotected high-voltage environment. Disturbances on electric power systems and lightning can cause GPR, voltage induction on telecommunications cables, power surges and high-voltage transients.

Service Performance Objectives (SPO)

Telecommunications service is expected to operate with a standard performance objective as outlined below:

- **Class A**
  – Service must be available before, during and after the fault event
- **Class B**
  – Service must function before and after, but not necessarily during, the fault event
- **Class C**
  – Interruptible, non-critical service

Levels of Protection

Standard protection devices are designed to work under the following GPR conditions:

- **Basic Protection Level I**
  – Cable stress below 300 Volts peak asymmetrical
  – All SPO classes of service (A, B and C)
- **Basic Protection Level II**
  – Cable stress below 1000 Volts peak asymmetrical
  – SPO Class B or Class C services
- **Basic Protection Level III**
  – Above 1000 Volts peak asymmetrical
  – Should require a High Voltage Isolator (HVI)
  – All SPO classes of service

Common Protection Devices

Protection devices listed below are designed to work under **Basic Protection Level I and II:**

- Carbon blocks
- Gas tubes
- Solid state protectors
- Solid state hybrid protectors
- Heat coils
- Spark gaps
- Mutual Drainage Reactors (MDR)

Protection devices listed below are designed to work under **Basic Protection Level III:**

- Lightning arresters
- High dielectric cables
- Isolation transformers
- Neutralizing transformers (Old technology)
- Copper HV isolators
- Fiber HV isolators

Electric Power System Telecommunications Equipment and Applications

There are many types of protective relaying and system control equipment used in the electric power industry which require communications circuits to clear faults, operate the system, protect personnel and equipment, and maintain system reliability.

Advanced protective relaying schemes that require "Class A" communications circuits are commonly used by the electric power industry to open High Voltage (HV) circuit breakers at remote locations. Examples of this type of equipment are listed below:

- **Protective relaying communications**

– Audio tones
– DC pilot wire relaying

- **Applications**

– Transfer trip
– Breaker failure
– Permissive overreaching
– Directional comparison

Electric power systems use "Class B" communications circuits for the following services:

- Supervisory Control and Data Acquisition (SCADA)
- Telephones for safety, metering and automation circuits

Ground Potential Rise (GPR)

The definition of GPR, according to IEEE Stds. 487 and 367, is...
". . .the product of a ground electrode impedance, referenced to remote earth, and the current that flows through that electrode impedance." The total station GPR is equal to the product of the station ground grid impedance and that portion of the total fault current that flows through it. In other words, GPR follows basic Ohm's Law calculations (i.e., voltage is equal to current times resistance).

When a ground fault occurs, fault current will divide among all circuit paths back to the source including metallic, earth return, etc. Metallic return paths include overhead ground wires, multi-grounded neutrals, bonding conductors, station ground grids, messenger wires, metallic cable shields and other conducting materials.

Zone of Influence (ZOI) and the 300-Volt Point

GPR decays outward in an exponential manner. The ZOI is the area around the ground grid dissipating the energy. Depending on soil resistivity and the size of the ground grid, the distance to the 300-Volt point on the ZOI can be calculated.

Total Electrical Cable Stress

The total electrical stress on a communications cable is the vectorial sum of the GPR and the induced voltage on the cable under fault conditions. When a faulting electric power line parallels an overhead or underground telecommunications cable, a potentially dangerous voltage is electromagnetically induced on the communications conductors. Excessive induction, by itself, can damage equipment and indirectly injure personnel.

Power and Lightning Fault Current Distribution

GPR will occur at several locations simultaneously. Fault current will divide among all circuit paths back to the source (metallic and earth return, for example) and create GPRs in the process. Metallic return paths include overhead ground wires, multi-grounded neutrals, bonds, station ground grids, and other conducting materials.

GPR Calculator

Applied Professional Training can provide a simple and convenient software program for calculating GPR, distance to any voltage point (i.e., 300V) and the voltage at any distance. (The GPR Calculator from APT's website www.aptc.com. See reference at front of booklet.)

Power Supplies

- Span power

  Copper twisted pair lines from telephone central offices commonly provide 48Vdc equipment power with limited current capability.

- Express pair

  When span power is unavailable or insufficient, additional non-circuit, dedicated cable pairs are sometimes used to power equipment.

- Local power

  Substations normally have 130Vdc and 120Vac source power available. Telecom equipment normally requires -48Vdc or 24Vdc power. Therefore, power supplies are used to match load requirements to available sources.

Common Questions about Engineering, GPR Calculations & Protection Equipment:

If you have any difficulty answering these common questions, then professional training is recommended.

1. What is a ground grid?
2. What is meant by remote ground and local ground?
3. What is needed at the 300-Volt point?
4. What does the fiber interface do?
5. What is the difference between rms, peak and asymmetrical peak voltage?
6. Do I need to consider GPR and induction issues separately or together?
7. Can induction cause a greater problem than GPR?
8. Do all circuits require power?
9. How much power does this equipment use, and how much of a drain is it on the battery bank?
10. What is simplex or loop power on a circuit?
11. Does the National Electric Code (NEC) and/or the National Electric Safety Code (NESC) address protection of my circuits?
12. Do any of these standards require me to install protection?

INSTALLATION

GENERAL INSTALLATION REQUIREMENTS

Please refer to manufacturer installation manuals and IEEE Standards for proper installation requirements.

- Follow IEEE Std. 487-2000, Guide for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations
- Follow IEEE Std. 367-1996, Recommended Practice for Determining the Electric Power Station GPR and Induced Voltage From a Power Fault

The HVI should be located on the substation's ground grid. The telephone company's C.O. cable should be connected to isolation jacks on the HVI or a non-metallic splice case. All metal mounting hardware used to attach the cabinet or backplane must be 6" or more from the entrance cable. All extra pairs should be properly capped and tie-wrapped out of the way. Do not place station side conductors within 6 inches of the remote side conductors.

Ground one side of the lightning arrester and the secondary protector block to the substation ground grid. Connect the cable shield to the opposite end of the lightning arrester.

Common Questions about Installation

If you have any difficulty answering these common questions, then professional training is recommended.

1. When and/or where should I use plastic vs. metal conduit?
2. How do I wire this equipment?
3. How do I install the different types of isolation equipment in the field?
4. Which system is easier, safer and cheaper?
5. What should be installed first?
6. Are there any construction pitfalls to avoid?

SAFETY

GENERAL SAFETY CONSIDERATIONS

Hazardous voltages can appear suddenly as a result of power faults or lightning strikes. Conductive objects (metal, damp saline soils, etc.) can become energized or carry a harmful potential that, if not properly protected, can cause serious injury. Safety of personnel can be achieved through education, proper facility design, and approved and tested insulated safety equipment. Personnel should use approved and tested rubber gloves and/or insulating blankets when working on the high-voltage interface (HVI) equipment.

GENERAL SAFETY CONSIDERATIONS

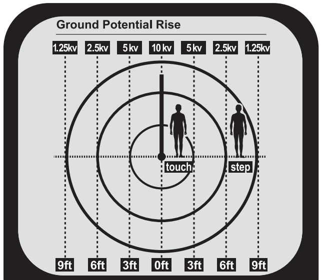


Figure 2: Touch and Step Potentials

Touch potential is the difference between the voltage gradient that one is standing on and the voltage gradient one is touching. A significant difference in touch potential can be hazardous.

Step potential is the difference in voltage gradients between a person's two feet. Shoes, gloves, etc. can provide insulation to touch and step potentials. Figure 2 shows the touch and step potentials.

BASIC PERSONAL SAFETY EQUIPMENT

Proper personal protection equipment, procedures and tools can help job safety and efficiency.

Rubber Gloves, Leather Protectors and Cotton Liners

All rubber gloves and other personal protection equipment have to meet safety standards established by national organizations like the American National Standards Institute (ANSI) and the American Society for Testing and Materials (ASTM). Examples of standard personal protection equipment are shown below:

Common Questions about Safety

If you have any difficulty answering these common questions, then professional training is recommended.

1. Why is safety an issue during equipment installation and maintenance?
2. What safety procedures should I follow when maintaining this equipment?
3. Do I have to use rubber gloves and a rubber mat all the time?
4. Must I use a 20-KV rubber mat?
5. What should I do if I come across a situation that needs protection?

CELL SITES ON ELECTRICAL TOWERS

Installing HVI equipment on cell sites is similar to substation installations.

Both copper and fiber optic high-voltage protection equipment are available for cell sites on regular and electric towers.

Each situation needs to be carefully analyzed for possible GPR problems. Proper isolation is a primary consideration. Electric power service (i.e., 120/240 Vac) can introduce a remote ground hazard.

Common Questions about Environments

If you have any difficulty answering these common questions, then professional training is recommended.

1. What is the difference between cell sites on electric towers and monopole sites
2. Can multiple wireless providers use only one tower and still have isolation?
3. Can optical ground wires cause safety hazards during istallation?
4. Can you use metallic shield optical cable with optical isolators?
5. When does isolation equipment require environmental controls (i.e., fans, heaters, etc.)?

DEFINITIONS

BONDING: The permanent joining of metallic materials to form a low-resistive electrical path for current to flow. Bonding usually refers to connecting metal objects together to form an equipotential.

CARBON BLOCK PROTECTOR: An assembly of two or three carbon blocks and air gaps designed to a specific breakdown voltage. These devices are normally connected to telecommunications circuits to provide surge protection and current paths to ground during surge conditions. Carbon blocks are non-restorable devices.

GAS TUBES: Gas tubes are similar to carbon blocks in operation except that the electrodes are metal sealed in a ceramic or glass envelope containing inert gasses to rapidly conduct high currents. They provide almost infinite impedance across the line, until triggered by an overvoltage. Gas tubes are self-restorable devices within specific limits.

GROUNDING: Establishes a low resistance path of metallic objects to the true earth ground reference. Grounding usually refers to providing an electrical path to true earth.

HEAT COIL: In-line device typically installed in central offices designed to fuse open during excessive sustained current in the loop.

HIGH DIELECTRIC CABLE: Cable that provides high-voltage insulation between conductors, between conductors and the shield, and between the shield and earth.

ISOLATION TRANSFORMERS: Isolation transformers provide longitudinal isolation of the telecommunication facilities from GPR fault conditions. They can be designed for use in a combined isolating drainage transformer configuration.

LIGHTNING PROTECTION: Provides a short low-impedance current path to ground. High-resistance paths for lightning energy can cause damage to property due to excessive heating or personal safety hazards due to a high GPR.

MUTUAL DRAINAGE REACTORS: These devices provide a circuit path for draining induced currents on telecommunications cables.

NEUTRALIZING TRANSFORMERS: These devices induce a counter voltage in opposition to the GPR voltage. These transformers or reactors are primarily used to protect telecommunication or control circuits at power stations or along routes exposed to power line induction, or both. Recent changes in IEEE 487-2000 call for periodic reengineering of the neutralizing transformer design and installation to ensure the equipment is capable of neutralizing the energy from the GPR event.

OPTIC COUPLING DEVICES: An isolation device using optical links to provide the isolation. Circuitry on both sides of the optical connection is used to convert the electrical signals into optical signals for transmission through the optical link.

SOLID-STATE PROTECTORS: A protective device that employs solid-state circuit elements. They provide both a high-speed voltage-limiting function and current sensing. Avalanche diodes are used as current limiters and crowbar devices, similar to Silicon Controlled Rectifiers (SCRs), to reduce current in the telecommunications circuit within nanoseconds. They are usually integrated into the terminal apparatus.

SPARK GAPS: Two electrodes having an air dielectric spacing. They are used to protect telecommunication circuits from damage due to voltage stress in excess of their dielectric capabilities.

Common Questions about Definitions

If you have any difficulty answering these common questions, then professional training is recommended.

1. What are analog data and POTS circuits?
2. What is Network Channel Terminating Equipment (NCTE)?
3. What is "total reach"?
4. What are secondary protectors?
5. What is meant by Basic Impulse Level (BIL)?
6. What type of card is required for my application?
7. When should a protection application be reviewed?

Typical ISOLATION EQUIPMENT

Figure 3: Copper Served HV Isolator

WIRE LINE ISOLATION

The equipment shown on the right is a typical standard isolator package including environmental control options. The central office (or remote) end of the service cable is connected to the red jacks on the lower left. Station equipment is connected to the secondary protector block located in the upper right-hand corner. See Figure 3.

FIBER LINE ISOLATION

The picture on the right shows a typical fiber optic HV isolator. The copper-to-fiber interface at the mid-span must be installed outside the ZOI. See Figure 4.

Figure 4: Fiber Served HV Isolator