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Grounding Issues at the Root of Many Power Quality Problems

Santa Clara — "In the world of electronics and equipment compatibility, few topics can elicit as much controversy as grounding," reports Tom Shaughnessy of PowerCET Corporation, author of the feature story on this important topic in this issue of *PQ Today*. "Simply asking about grounding can bring forth a wide range of opinions and it becomes very evident that the implementation of grounding in the field reflects this diversity in grounding concepts."

If concerns about grounding were strictly relegated to power grounding, the topic would be complicated enough. However, specialized grounding techniques have evolved to meet the perceived grounding requirements of electronic equipment.

Terms such as single point grounding, multiple point grounding, isolated grounding, and equipotential reference grounding are among a host of terms which reflect varying grounding ideologies.

"In some cases, grounding practices have evolved out of desperate measures to keep electronic equipment working in the field. So what worked once or twice in the past has become the de facto approach to all grounding requirements," Shaughnessy reports.

"Grounding need not be complicated, but when a lack of understanding mixes with folklore and tradition, grounding can become exceedingly complex. Worse yet, the combination of ignorance and misguided installation practices may contribute to interference potentials at a site and actually degrade overall equipment performance."

"In these instances, equipment may perform poorly and erratically and equipment reliability may become so unpredictable that equipment operators, when asked, may recount ghostly, ongoing equipment performance problems and even suggest the use of an exorcist!"

Tom Shaughnessy's presentation, beginning on page 5 with a historical perspective on this controversial subject, proves that a careful and scientific approach to grounding is possible. And with proper grounding, the susceptibility of sensitive electronic equipment to problems ranging from lightning damage to data errors can be minimized.

SEE CENTER SPREAD FOR MORE ON
Grounding

Dranetz Technologies and BMI Forge Power Quality Alliance

Santa Clara — Basic Measuring Instruments (BMI) and Dranetz Technologies, the two oldest and most-respected names in power, harmonics and energy monitoring technology have joined forces to form a partnership that, according to Bill Stuntz, President and CEO, "is uniquely positioned to respond to the changing requirements of this dynamic marketplace."

Together, Dranetz and BMI form the largest, strongest and most stable company in the industry with combined sales exceeding nearly 5 times that of the nearest competitor.

"For many, the name 'Dranetz' is synonymous with power quality, harmonics and energy analysis instrumentation," Stuntz recently wrote. "Dranetz Technologies pioneered this technology in the mid 1970s. Then, through a decade of vigorous competition, Dranetz and BMI literally created the market, as we know it, for these products. Today, thanks to Dranetz and BMI, we have the tools to better understand the electrical environment and to solve the problems the environment creates for sensitive electronic equipment."

According to Paul Golden, Director of Marketing and Sales, "The consolidation of these two world-class companies has resulted in significant, immediate benefit to customers by offering the widest selection of hardware and software solutions tools. The combined Dranetz/BMI product family covers the gamut in terms of capability and features in both portable and permanently installed products and systems."

"With complete facilities located on both the east and west coast, Dranetz/BMI also is in the position to provide the highest degree of technical support to our customers."

"In addition," Golden continued, "this new alliance brings together experts from both companies that have been independently tackling the technical issues that will drive new product innovations in the years to come."

The new Dranetz/BMI is part of the WPT family of companies that also includes Electrotek Concepts, a world-recognized power quality software technology and consulting firm.

INSIDE THIS ISSUE

FOR THE RECORD

PQ for the Year 2000... and beyond

Bruce Lonie

The year 2000 is the symbol of change. It will bring with it a host of new opportunities and problems, and power quality and the electrical environment will be no exception. Our society is becoming more dependent on electronic systems and equipment while at the same time we are undergoing deregulation —a fundamental change in our electric utility infrastructure!

In recognition of these and other changes, PowerCET has announced a major restructuring of the power quality knowledge-based education programs.

Power Quality for the Year 2000 and Beyond replaces the popular three-day Power Quality: Problems, Analysis & Solutions course and adds new sections on networks and facility hardening.

The two-day Advanced Power Quality course has been replaced with the Advanced Power Quality Curriculum—a series of 5 one-day courses. The new course series provides a more in-depth coverage of the subject areas—harmonics, adjustable speed drives, grounding, equipment sensitivity and facility hardening.

All PowerCET course offerings are available as in-house programs. In-house programs may become cost effective with as few as 6 to 7 students. Contact PowerCET for cost estimates.

In addition to the regularly scheduled skills-based training programs on the various Dranetz and BMI equipment, PowerCET is developing a series of videotape programs for students. The first such program on the Dranetz Model 4300 Power Platform will be released in July 1997.

Bruce Lonie is President of PowerCET Corporation. You can contact him at bruce_l@powercet.com.

Lightning Risk Analysis – Figure the Odds Like Rolling Dice

"Mike the Strike" Stringfellow, PowerCET Corporation

Many years ago, in my electric utility days, I was involved with a project investigating lightning strikes to overhead electricity distribution lines. For a number of years, we carried out measurements on a six-mile experimental line, built and instrumented for the purpose. Video recorders and automatic cameras enabled us to locate where every lightning flash struck within a mile or two of the line. Three stations equipped with oscillographic recording equipment and simple magnetic detectors on every pole of the line enabled us to get an accurate picture of lightning currents and voltages, including where direct strikes occurred. Flash counters gave us a pretty good measure of the lightning ground flash density in the vicinity of the line–about 17 per square mile per year.

Before the project started, several of the lightning experts on the project, myself included, made estimates of the number of lightning strikes we would expect to the line each year.

Using electrogeometric models (which calculate the striking distance of lightning based on the electric charge on the descending lightning leader and the geometry of the line), we came up with estimates that were between 3 and 4 strikes per year.

The first year produced a verified 4 strikes to the line, causing us all to congratulate ourselves on the accuracy of our predictions. The second year produced 6 strikes–a bit high, maybe, but not too high to be out of the question. The third year produced a whopping 15 strikes, and the start of massive doubts on the accuracy of our modeling.

The first eight years' measured strike data for this line are given in Table 1. Three things are apparent from this data :

1. The yearly strike incidence varied over wide limits (4 to 15).
2. The strike incidence showed no relation to ground flash density.
3. Our original estimates of flash incidence to the line were wrong by about a factor of two!

Year	Ground Flash Density	Direct Strikes to Line
1	16	4
2	17	6
3	15	15
4	15	8
5	15	5
6	16	7
7	24	9
8	17	10
Mean	17	8

Table 1.

Although the average strike frequency is 8 per year, in only one year did we actually see 8 strikes! In some years there were more, in some there were fewer. It turns out that this yearly variation can be explained by the statistical nature of lightning. Some flashes strike the line, some don't, and it's unpredictable–just like the roll of dice. And in the same way that you can calculate the chance of throwing "snake eyes" in any given number of throws, you can calculate the number of lightning flashes that fate will roll your way.

The probability of lightning strikes to a specific structure is described by the Poisson distribution–a special case of the statistical binomial distribution which unweighted dice obey. Once you know the long-term average number of strikes to a structure, you

LIGHTNING RISKS CONTINUED (PG.9)

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IEEE Corner–
Power Quality Standards Undergoing Revision

Rich Bingham, Dranetz/BMI

There are numerous groups within IEEE that are developing or revising standards and recommended practices relating to power quality.

To minimize redundant efforts, the Standards Coordinating Committee (SCC) 22 on Power Quality authorizes and monitors task force and subcommittee efforts. Though the majority of the work is done under the Power Engineering Society (PES), contributions are also being made by the Industrial Applications Society (IAS). Coordination also exists between the IEEE and the international societies, such as CIGRE, CIRED, and CENELEC in an attempt to harmonize standards throughout the world.

Key Standards are being Updated

Three of the most prominent efforts are the IEEE Std 1100-1992, *Recommended Practice for Powering and Grounding Sensitive Electronic Equipment* (also known as the Emerald Book); IEEE Std 1159-1995, *Recommended Practice for Monitoring Electric Power Quality;* and IEEE Std 519-1992, *Recommended Practice on Harmonics in Power Systems*. All three groups are working on revisions:

- The new Emerald Book will include an expanded chapter on telecommunications grounding.
- IEEE 1159 has three task forces: *Data Acquisition Attributes Required for Recording PQ Events; Characterization of PQ Events* (now focusing on voltage sags); *Data Transfer Format* (working to standardize formats to allow software to read/display data from monitors of different vendors).
- An applications guide will provide assistance in applying the harmonic limits and concepts of IEEE 519.

Other IEEE Standards Activity

- *P1433*. Compiling and attempting to resolve discrepancies between PQ definitions from a variety of recognized sources.
- *P1409*. Producing a Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1KV through 38KV (including the application of static-transfer-switches, static series and shunt compensators and other custom power solutions).
- *P1346*. System Compatibility aimed at keeping processes running properly.
- The *Working Group on Power System Harmonics*. Has task forces in addition to 519A working on Harmonic Limits for Single Phase Equipment, Modeling and Simulation and Interharmonics.

A More Detailed Look at IEEE 1159

IEEE Std 1159 is the result of nearly ten years work, with committee members from the electric utilities, industrial companies, and PQ monitor vendors and consultants. It is a useful document for those beginning to deal with power quality-related issues, as well as those who have been doing such for a while.

There are sections on power quality phenomena, monitoring objectives, measurement instruments, application techniques, interesting power monitoring results, and a bibliography of other sources of information and solutions.

One of the most significant contributions of IEEE 1159 to the power quality community is the definition and classification of power quality phenomena, shown in Table 1, Categories and Typical Characteristics of Power System Electromagnetic Phenomena.

Rich Bingham is Manager of Products and Technology at Dranetz/BMI. You can contact him at rbingham@dranetz.com.

Categories		Typical Duration	Typical Voltage Magnitude
Transients			
	Impulsive	nsec to msec	na
	Oscillatory	3 msec - 5usec	0-8 pu
Short Duration Variations			
	Instantaneous Sag	0.5 - 30 cycles	0.1 - 0.9 pu
	Instantaneous Swell	0.5 - 30 cycles	1.1 - 1.8 pu
	Momentary Interruption	0.5 cycles - 3 sec	less than 0.1 pu
	Momentary Sag	30 cycles - 3 sec	0.1 - 0.9 pu
	Momentary Swell	30 cycles - 3 sec	1.1 - 1.4 pu
	Temporary Interruption	3 sec - 1 min	less than 0.1 pu
	Temporary Sag	3 sec - 1 min	0.1 - 0.9 pu
	Temporary Swell	3 sec - 1 min	1.1 - 1.4 pu
Long Duration Variations			
	Sustained Interruption	longer 1 minute	0.0 pu
	Undervoltage	longer 1 minute	0.8 - 0.9 pu
	Overvoltage	longer 1 minute	1.1 - 1.2 pu
Voltage Imbalance			
		steady state	0.5 - 2%
Waveform Distortion			
	DC Offset	steady state	0.5 - 2%
	Harmonics	steady state	0 - 20%
	Inter-harmonics	steady state	0 - 2%
	Notching	steady state	na
	Noise	steady state	0 - 1%
Voltage Fluctuations			
		intermittent	0.1 - 7%
Power Frequency Variations			
		less than 10 sec	na

Table 1. Categories and Typical Characteristics of Power System Electromagnetic Phenomena

FOR THE RECORD

Power Analysis Technology... Raised to the Power of 2

Bill Stuntz

With the advent of power marketing, the entire character of power delivery is changing. Soon, it will not be just a matter of energy costs, but also guaranteed energy quality that will be the basis for selection of an electrical energy provider.

So it seems all the more fitting that, at this dynamic point in time, the two companies that have pioneered the science of power quality and energy monitoring should join forces.

Dranetz Technologies and Basic Measuring Instruments are now one, and together, we are bringing power monitoring technology to new levels. Together, Dranetz/BMI is not only the largest manufacturer of power monitoring instrumentation, we have the greatest depth in technology, experience, manufacturing capacity and installed base. So we have the core competencies and the vision to design new systems and products to meet the needs of this rapidly-changing market.

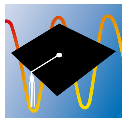
Examples of our responsiveness to market needs include the new BMI PQNode® 7100-S that is designed to physically replace strip chart recorders in switchgear panels. Another is the revolutionary Dranetz Power Platform® 4300, the hand-held power and energy analyzer that carries the power of larger systems in a package priced to fit into an electrical contractor's tool box.

The new Dranetz/BMI is committed to providing the tools needed to serve the new era in power delivery. Our products will continue to answer the needs of this diverse market–from the utility substation to the factory floor.

Bill Stuntz is President and CEO of WPT Corporation. You can contact him at bills@electrotek.com.

Flickering Lights–A Case of Faulty Wiring

Chris Melhorn, Electrotek Concepts



One of the most common power quality problems in residential and commercial facilities is missing or loose connections.

Approximately 70 to 80 percent of all power quality related problems can be attributed to faulty connections and/or wiring. This article describes a case study involving a wiring and grounding problem in a residential dwelling.

Residential systems are served from single-phase transformers employing a split secondary winding, often referred to as a single-phase 3-wire system. This type of transformer is used to deliver both 120 Volt and 240 Volt single-phase power to the residential loads. The primary of the transformer is often served from a 12KV to 15KV distribution system by the local utility. Figure 1 illustrates the concept of a split phase system.

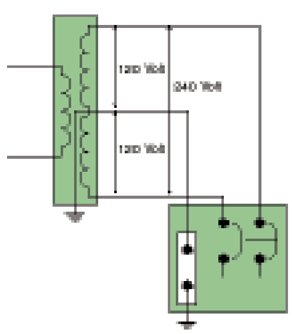


Figure 1.

When this type of service is operating properly, 120 Volts can be measured from either leg to the neutral conductor. Due to the polarity of the secondary windings in the transformer, the polarity of each 120 Volt leg is opposite the other, thus allowing a total of 240 Volts across both legs, as illustrated. The proper operation of this type of system is dependent on the physical connection of the neutral conductor or center tap of the secondary winding. If the neutral connection is removed, 240 Volts will remain across the two legs, but the line-to-neutral voltage for either phase can be shifted, causing either a low or high voltage from line to neutral.

Figure 2.

Most loads—lighting, televisions, microwaves, home electronics, etc.—in a residential dwelling are operated from 120 Volts. However, there are a few major loads that incorporate the use of the 240 Volts available. These loads include electric water heaters, stoves and ovens, clothes dryers, heat pumps, etc.

In this case, there were problems in the residence that caused the home owner to question the integrity of the power system serving his home. On occasion, the lights would flicker erratically when the washing machine and dryer were operating at the same time. When large single-phase loads were operated, low power incandescent light bulb intensity would flicker.

Measurements were performed at several 120 Volt outlets throughout the house. When the microwave was operated, the voltage at several of the 120 Volt outlets would increase from 120 Volts nominal to 128 Volts. The voltage would return to normal after the microwave was turned off. The voltage would also increase when a 1500 Watt space heater was operated. It was determined that the voltage would decrease to approximately 112 Volts on the leg from which the large load was served. After the measurements confirmed suspicions of high and low voltages during heavy load operation, finding the source of the problem was the next task at hand.

The hunt began at the service entrance to the house. A visual inspection was made of the meter base and socket after the meter was removed by the local utility. It was discovered that one of the neutral connectors was loose. While attempting to re-tighten this connector, the connector fell off of the meter socket into the bottom of the meter base (see Figure 2).

Could this be the cause of the flickering voltage? Let’s examine the effects of the loose neutral connection.

Under normal conditions with a solid neutral connection (Figure 3), load current flows through each leg and is returned to the source through the neutral conductor.

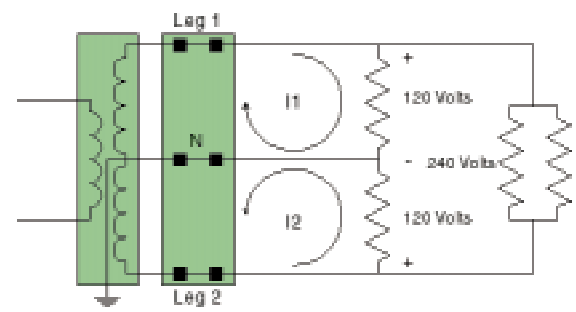


Figure 3.

There is very little impedance in either the hot or the neutral conductor; therefore, no appreciable voltage drop exists.

When the neutral is loose or missing, a significant voltage can develop across the neutral connection in the meter base, as illustrated in Figure 4.

When a large load is connected across Leg 1 to N and the other leg is lightly loaded (i.e., Leg 1 to N is approximately 10 times the load on Leg 2 to N), the current flowing through the neutral will develop a voltage across the loose connection. This voltage is in phase with the voltage from Leg 1 to N' (see Figure 4) and the total voltage from Leg 1 to N will be 120 Volts. However, the voltage supplied to any loads connected from Leg 2 to N' will rise to 128 Volts, as illustrated in Figure 4. The total voltage across the Leg 1 and Leg 2 must remain constant at 240 Volts. It should be noted that the voltage from Leg 2 to N will be 120 Volts since the voltage across the loose connection is 180 degrees out of phase with the Leg 2 to N' voltage.

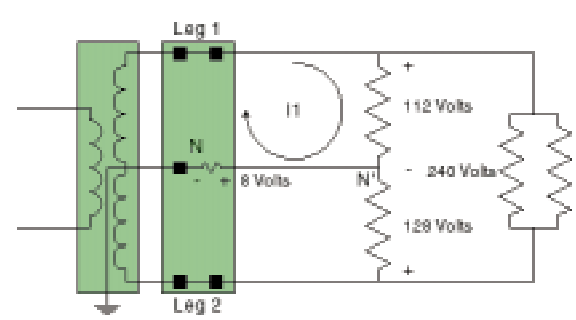


Figure 4.

Over time the neutral connector had become loose. This loose connection caused heating, which in turn caused the threads on the connector to become worn, and the connector failed. After replacing the connector in the meter base, the flickering light phenomena disappeared.

On systems of this type, if a voltage rise occurs when loads are energized, it is a good indication that the neutral connection may be loose or missing.

Chris Melhorn, Manager of Industrial & Utility Studies at Electrotek Concepts can be contacted at chrism@electrotek.com.

Grounding: A Historical Perspective

Tom Shaughnessy, PowerCET Corporation

Grounding, as a point of divergent technological approach, has been around from the first uses of electricity.

Early on, Edison implemented a floating approach for his DC systems after several events demonstrated the adverse effects of stray DC currents flowing throughout buildings and neighborhoods. Once, a horse was shocked when it walked on "electrified soil" near Edison's Pearl Street generating station and laborers working on his underground distribution system believed there was a "devil in the wire."[1] As a result of some of these problems, Edison apparently adopted a three wire system which did not rely upon earth return.

> *"In order to demonstrate the inherent safety of his ungrounded DC system, Edison used AC power in public demonstrations in which he electrocuted stray dogs and cats."*

In contrast, the Westinghouse/Tesla system of alternating currents was solidly grounded (earthed).

Edison attempted to use this difference to demonstrate that the DC system was inherently safe whereas the AC system was not safe. To this end, Edison used AC power in public demonstrations in which he electrocuted stray dogs and cats.

At one point, Edison even electrocuted an elephant! Had the Westinghouse/Tesla AC system been floated as was the Edison system, then this point of debate would never have arisen.

However, the polyphase alternating current system benefited from rigorous grounding, and so the controversy raged on.

[1] *IEEE Industry Applications*, May/June 1996.

Unfortunately for Edison, the economic advantages of the AC electrical system were simply too great and that approach prevailed.

Formal Practices Established in 1971

Grounding practices in the United States were more formally defined in 1971 when the National Electrical Code mandated grounding. The changes in the code followed a tragic underground mine fire in West Virginia in 1969. This fire also led to the establishment of OSHA, the Occupational Safety and Health Administration in 1970.

The practices of grounding which were first introduced for AC systems in 1885 by Elihu Thomson were thus formally codified, forming the benchmark for grounding rules which are now, for the most part, nationally implemented and recognized.

The decision to ground or not to ground an electrical system still serves as a point of argument both internationally and nationally. Some countries (like the United States) use a solidly grounded distribution system, whereas some European and Latin American countries may ground (earth) only at the power source. In Japan, resistance grounding may be used with differing "classes" of grounding.

Is any approach better? Probably not, although, the equipment designed for use with a particular type of grounding may not work well in other applications in which differing grounding processes are used.

There are other considerations: A solidly grounded system may be less costly to implement, but stray currents then become a possible consequence; Stray currents are less likely with a floating system, but a floating system may require additional instrumentation to detect system faults and require the use of higher insulation ratings.

Within the United States, some commercial and industrial applications still use floating AC systems. However, most utility AC distribution systems are solidly grounded and the grounding connections may be interconnected via the utility neutral. Stray currents can exist, but the magnetic sphere of influence surrounding power transmission and distribution lines increases the reactance of external paths and tends to confine the extent and the magnitude of earth related currents. The electrical service entrance for facilities connected to the utility system are also solidly grounded. Therefore, within the United States, we are accustomed to the practice of grounding electrical systems. Grounding serves the primary functions of referencing AC systems and providing a means to ensure fault clearing. The impedance of the system is viewed from a perspective of power frequencies and immediate harmonics (e.g., 60 Hz and associated harmonics).

Grounding Practices Derived from Practical Requirements

The evolution of grounding practices was not restricted to AC power systems. Grounding practices also arose to support telegraph, telecommunications and radio broadcasting. In each case, grounding concepts were developed to meet the operational requirements of the respective systems.

Pre-dating the grounding requirements of AC systems, telegraph equipment introduced in the 1800s was intentionally earthed and in some cases telegraph systems used earth return as a signal path. Therefore, a very solid DC reference with respect to earth was required. With the advent of the telephone in the latter part of the 19th century, the reliance upon earth reference continued. DC reference again was essential. In fact, earth reference is still essential in some modern telephone systems: In two-way trunk networks, ground start signaling is used to prevent telephone traffic collisions. In both telegraph and telecommunication systems, the focus on grounding revolved around DC reference.

History of Grounding Continued (pg.9) ▶

CENTER SPREAD FEATURE

Facility & Equipment Grounding

by Tom Shaughnessy, PowerCET Corporation

The primary goal of grounding throughout a facility is safety. Grounding is implemented to ensure rapid fault clearing and to prevent hazardous voltage rise during a fault. As such, good grounding reduces the risk of fires or injury to personnel.

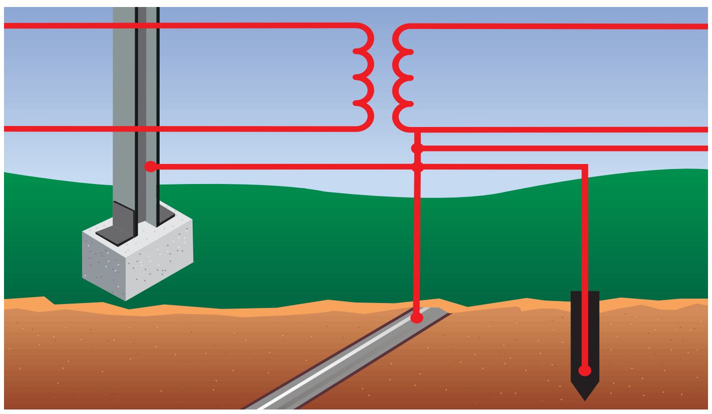


Figure 1. NEC-Prescribed Service Entrance Grounding

The National Electrical Code (Figure 1) goes into great detail describing the processes by which a grounding electrode system should be established for a facility. In essence, at the electrical service entrance, the neutral of the incoming electrical service is bonded to building structural steel, the incoming water pipes, and to driven ground rods.

The bonding ensures continuity between any metallic structure in the facility which might be energized during a fault and serves to "reference" the AC voltage with respect to earth. Establishing the facility grounding electrode system effectively holds the electrical service at earth potential. The terms earthing and grounding are frequently used interchangeably within the US, although outside the US the terms may have very unique meaning.

From the electrical service entrance, grounding extends out contiguously and continuously along with power conductors to points of use throughout the facility. The grounding must be integral because the inductive effects caused by any grounding conductor placement which is separate and distant from that of the phase conductors could negate fault clearing and cause undue voltage rise in faulted equipment.

When the US adopted the three wire system (one live, one neutral and one grounding conductor for single phase circuits), the intent was to prevent the dual use of a conductor as both a grounding and current carrying conductor. Thus the National Electrical Code (NEC) refers to intentional current flow in the grounding means as objectionable ground current.

In reality, current does flow in the grounding conductor and there exist some very interesting exceptions (e.g., electric ranges and clothes dryers). Two normal sources of current flow in the grounding of a facility are power frequency leakage currents and high frequency emissions from electronic equipment. The leakage current from any single device is limited by both UL and the FCC, but as equipment density increases in a facility, so does the magnitude of current flow in the grounding of the facility.

Suspect Grounding Schemes

The practice of grounding facilities and equipment would be fairly straightforward were it not for electronic equipment. When designers of computers referenced the logic circuits in equipment to the AC safety ground, the Pandora's box of grounding was opened. With the logic circuits referenced to the equipment chassis ground, any small amount of chassis potential caused by current flow in the grounding of the device could cause reference error in the equipment. During the early days of electronic equipment development, many differing grounding scenarios became popular. Supplemental grounding, isolated grounding and the "one-Ohm-ground" are among the more infamous of grounding schemes which arose during this interval.

Supplemental Grounding

In practice, supplemental grounding is frequently achieved by driving a ground rod close by the device and an external grounding conductor then connects the ground rod to the chassis of the "grounded" device. There is a myriad of potential problems caused by this practice. Some of the worst problems include the formation of transient current flow through the chassis of the device and the risk of sinking facility fault currents through this grounding connection. In addition, the NEC requires that supplemental grounding must meet the provisions of the code which pertain to the establishment of the facility grounding electrode system. This means that the grounding must be permanent, continuous and capable of handling any fault current imposed onto it. In turn, this means that plug-connected 12 gauge equipment grounding wires do not qualify. Supplemental grounding is a bad idea and should be avoided.

The "One Ohm Ground"

A frequently mentioned criterion, the establishment of a grounding system with one-Ohm of resistance to earth, is found in many equipment installation specifications. The NEC requires only 25 Ohms of resistance for made electrodes and ANSI/IEEE Standard 141-1986, *Electric Power Distribution for Industrial Plants* (IEEE Red Book), specifies a grounding resistance of 1 to 5 Ohms for large commercial facilities. In truth, the resistance of the facility grounding electrode system is important primarily because excessive resistance would lead to a large voltage rise during fault conditions. But, one Ohm of resistance at what frequency? If a facility has one Ohm of resistance as measured with a DC measurement device at the service entrance, the impedance of this grounding system will hardly be the same at a megahertz! The value of resistance at the service entrance is less important when the impedance between the equipment and the service is considered. Finally, the leakage currents of equipment do not return to the earth: Power frequency leakage currents return to the derived source and high frequency leakage currents return to the equipment which generated the currents.

Isolated Grounding Systems

The NEC allows the use of isolated grounding systems to help reduce the effects of localized electromagnetic interference. In an NEC-compliant isolated grounding system, the receptacles used to power equipment are built without a bond between the grounding screw and the mechanical ground for the receptacle box. The receptacle is grounded with an insulated grounding conductor. The insulated grounding conductor must be installed in the same conduit or raceway as the current carrying conductors. The insulated grounding conductor may pass through one or many electrical panels without attachment to the mechanical ground at those panels, but it must terminate within the derived power source serving the equipment.

Problems with isolated grounding systems arise when the grounding conductor bypasses the derived service and terminates, for instance, at the 480 Volt service entrance rather than at the 208 Volt service which powers the equipment.

Other problems include elevated chassis potential caused by induced voltage in multiple circuit raceways and the termination of grounding at totally separate grounding points. Isolated grounding systems must be used with intelligence and care.

The Grounding Dilemma

The dilemma facing those attempting to ground equipment is complex. What happens to the power frequency leakage currents? What happens to the high frequency leakage currents? Is conduit ground adequate? How many devices can be "grounded" with a single conductor? How can one avoid chassis potential? Do data networks have any effect? What can be done to limit the effects of ground referenced interference? The list of questions goes on.

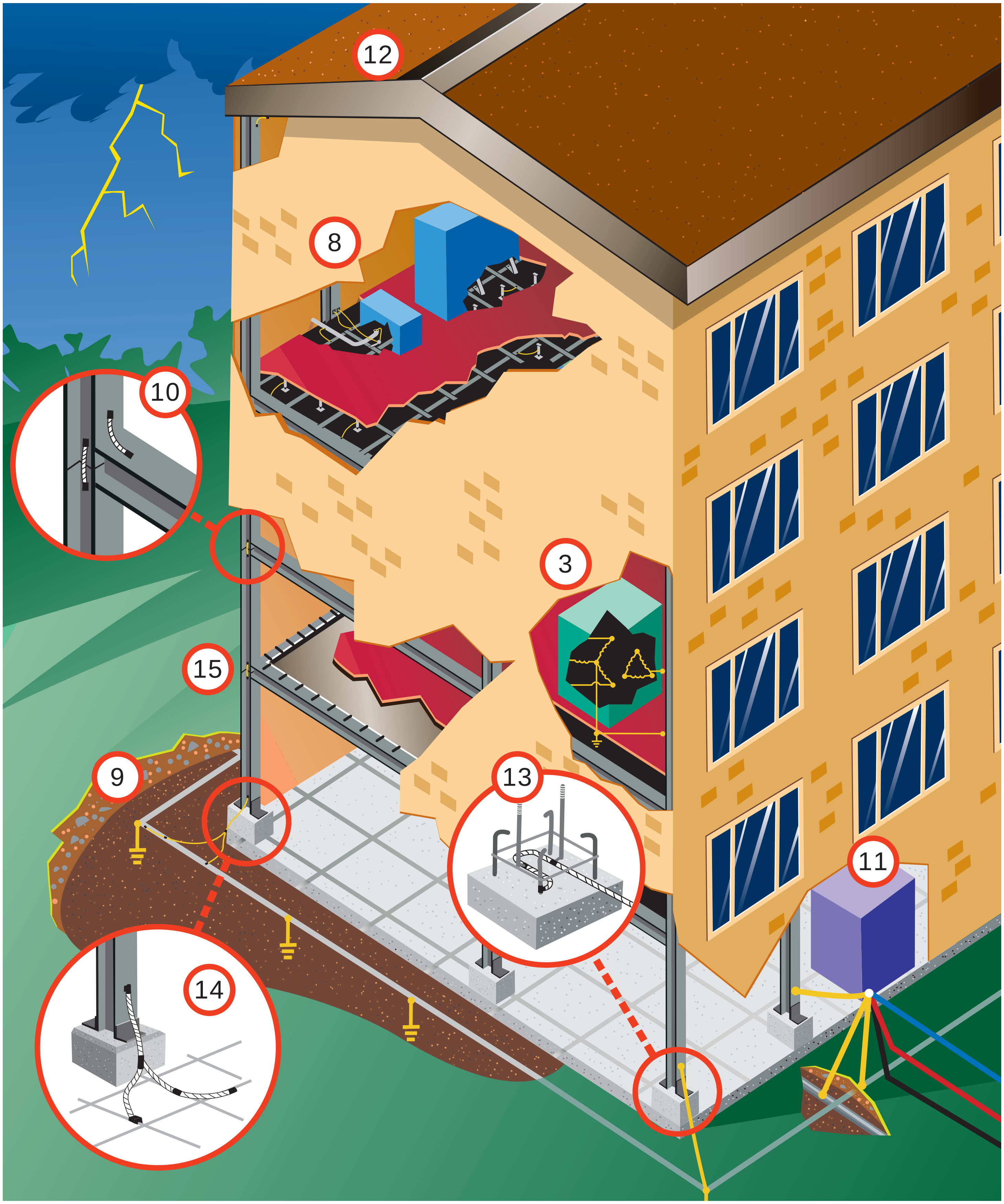
Grounding for Equipment Performance

If there is any simple truth about equipment grounding, it is the fact that equipment grounding is won and lost at the system. External changes in grounding may affect the ultimate functionality of the system, but changes in external grounding cannot correct grounding problems which are inherent in the equipment itself. This does not mean that efforts to improve equipment grounding are fruitless. On the contrary, improving the grounding for equipment can make quite a difference.

For instance, the reference grid described in FIPS PUB 94 *(Federal Information Processing Standards Publication—Guideline on Electrical Power For ADP Installations)* works well for equipment contained within the confines of a computer room. Unfortunately, reference grids cannot be implemented everywhere.

Good grounding for a facility establishes the base for better equipment operation within the facility. It entails a low ohmic value for earth reference at the service entrance. And it also requires that reference be maintained throughout the facility without compromising fault clearing. Meeting this condition can entail:

1. Parity sized grounding conductors throughout
2. Grounding symmetry in all parallel feeders
3. Zones of equipment with localized transformation to isolate the equipment and to control leakage currents
4. Limiting the quantity of devices grounded by any single grounding conductor
5. Using specialty transformers with integral grounding impedance to limit ground referenced interference propagation
6. Faraday cage design concepts for facility construction
7. Use of differential networks throughout the facility as opposed to single ended data networks



8. Reference grids in all computer, data processing, and information technology rooms
9. Perimeter ground ring bonded to service entrance structural steel
10. Intentional continuity of structural steel
11. Bonding all communications cables to structural steel (telephone, cable TV, security systems, data networks) at the immediate point of entrance into the facility
12. Architectural steel treatment for lightning control
13. Ufer ground treatment per NEC for all main vertical steel footers
14. Grounding grid below moisture barrier
15. Bonding horizontal steel pans to structural steel

If care and attention are given to the grounding of a facility and the equipment within the facility, then the facility will take care of you: Ignore facility and equipment grounding and the grounding gremlins will TAKE CARE OF YOU!

7100-S PQNODE® REPLACES SWITCHGEAR/ SWITCHBOARD PANEL CHART RECORDERS

Santa Clara, CA — Dranetz/BMI announces the introduction of the BMI 7100-S PQNode power monitoring system. This new version of the popular BMI 7100 PQNode is packaged in a sheet metal enclosure for direct installation into metal-clad switchgear and switchboards.

The unit is designed to replace existing electromechanical chart recorders with a minimum of retrofit effort while providing greatly enhanced monitoring capabilities. Installation is further simplified by means of direct connection to voltage and 5A current circuits via screw-type terminal connections on the rear of the instrument. Phone line connection to an optional 14.4KB modem is also made at the rear of the unit. A GPS receiver option for precise time stamping is also available.

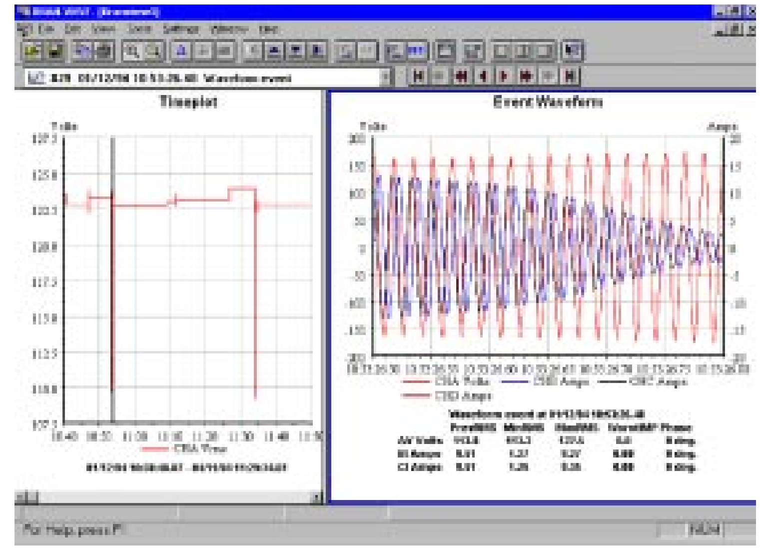
The 7100-S provides eight-channel, simultaneous voltage and current monitoring of power quality, power flow or harmonics. Setup and data retrieval are performed from a PC running Power Evaluation Software (PES) for Windows via the serial port or by means of an optional modem. The instrument configuration is determined by the installed firmware and setup by the Power Evaluation Software:

- *Power Quality Mode:* snapshots, rms summaries, rms variations, impulses, waveshape faults, demand (kW and kVA), harmonic snapshots to the 49th, kWh
- *Power Flow Mode:* Vrms, Irms, demand (kW and kVA), kWh, kVAR, PF, dPF, Vthd, Ithd
- *Harmonics Mode:* Vthd, Ithd, individual harmonics to the 49th, individual harmonics triggering, 1- or 4-cycle FFTs

All Dranetz/BMI products come with a one-year hardware warranty and one-year software support.

Price:	$4,565
Availability:	Now
Delivery:	4-6 weeks

NEW DRAN-VIEW® 658 SOFTWARE OPENS WINDOWS TO POWER QUALITY AND HARMONICS ANALYSIS



Edison, NJ — DRAN-VIEW 658, a new Windows-based power quality and harmonics analysis software package for the industry-standard Dranetz Model 658 Power Quality Analyzer, is now available from Dranetz/BMI. This new software package operates with the Windows 3.1, Windows 95 and Windows NT operating systems.

Utilizing data acquired from the Dranetz 658, DRAN-VIEW 658 provides viewing of timeplot and waveform data, simultaneously in a two-pane browser. This linked, simultaneous browsing of event and trend data is a unique feature of DRAN-VIEW 658. (Data from 658 data disks or previously processed using Dranetz GHA software can also be viewed.) Multiple channels of data can be overlayed in both the timeplot and waveform panes.

Harmonic timeplots, including 3-D harmonic timeplots (with optional driver installed), and FFT charts can be displayed in the two-pane browser. FFT computations are performed over user-selected waveform intervals.

The DRAN-VIEW 658 software includes a pull down event list to quickly and easily locate specific disturbances. Multiple level zoom functions are performed with a click of the mouse in either pane.

All data can be converted for export into spreadsheet/database programs. In addition, the software is equipped with a powerful report generation capability complete with customized event and summary graphics. Reports can be directly printed from DRAN-VIEW 658 or exported to MS-Word or other word processing software.

DRAN-VIEW 658 will also read data from the Dranetz Power Platform® PP1; Power Platform 4300 and Dranlogger® when equipped with optional driver and disks.

All Dranetz/BMI products come with a one-year hardware warranty and one-year software support.

Price:	$595
Availability:	Now
Delivery:	3-5 days

For more information call: 1-800-DRANTEC (east coast); or 1-800-876-5355 (west coast)

POWERCET INTRODUCES PP4300 VIDEO TRAINING PROGRAM

Santa Clara – A new operational training course for the Dranetz Power Platform 4300 is now available on videotape from PowerCET Corporation.

The training course is designed to provide a complete understanding of the operational characteristics of this powerful new instrument and its various TASKCard configuration cards.

The self-contained course is made up of four modules contained on two VHS videotapes:

- Hardware Familiarity
- Real-time and *Easy Start* Monitoring
- Advanced Monitoring
- Viewing Event Data

A comprehensive study guide is included.

Individuals who complete the course and pass a self-administered test are eligible to receive a certificate of achievement.

Contact PowerCET Corporation at 408-988-4645 for complete details.

NEW DRAN-LINK™ SOFTWARE ENABLES REMOTE PC LINK TO POPULAR POWER QUALITY ANALYZERS

Edison, NJ– A new Windows 95/Windows NT software utility that enables remote communication between a PC and Dranetz Model 658 and Power Platform PP1 Power Quality Analyzers is now available.

DRAN-LINK is a communications object that enables the user to connect the PC to the selected Model 658 or PP1 via Hayes-compatible modem or RS-232 serial communications.

With DRAN-LINK installed the user can select a remote device to be accessed from stored phonebook, gather data from the remote location and store it in the PC.

Once data is downloaded, DRAN-LINK automatically launches DRAN-VIEW 658 and reads the data. Analyzer memory can also be reset by remote command using DRAN-LINK.

In addition to gathering data, DRAN-LINK also supports the remote, real time Meter Mode for the PP1 which provides display on the PC of current readings taken by the selected PP1.

For more information call: 1-800-DRANTEC (east coast); or 1-800-876-5355 (west coast)

CASE STUDY 4

Illegal Neutral -to- Ground Bond

Environment

Computer controlled navigation training simulator located on a college campus. The system was newly installed on the third floor of a classroom building and consisted of four microcomputers linked to drive a video projection screen.

Problem

Glitches in the video display consisting of wavy lines and other distortion.

Measurements

The systems engineers found that symptoms decreased when certain ground wires were temporarily disconnected. With this information, the possibility of a grounding problem in the AC wiring was explored. The first measurements taken seemed to indicate that grounding was satisfactory. A plug-in tester indicated safety ground wiring was good, and a DVM read only 0.33 Volts between neutral and ground at the outlets.

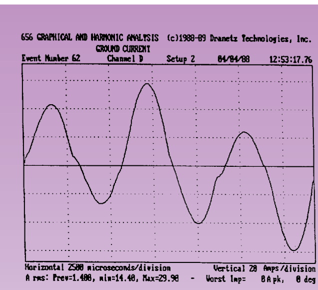


Figure 1. Conduit current: mostly third harmonic (180Hz) and obviously modulated by the 60 Hz fundametal.

A thorough visual inspection of the wiring, however, revealed that there was a problem. The neutral and ground busses were bonded in the local distribution panel—a common error. The neutral return current was also being carried by the conduit ground all the way to the basement service entrance. A power monitor showed this conduit current to be 25 Amperes, mostly 3rd harmonic. (See Figure 1.)

Solution

The symptoms disappeared as soon as the illegal bond was removed and the safety ground returned to a zero Volt reference.

Lightning Risk Analysis

(continued from pg.2)

can calculate the probability of getting a certain number in any particular year. The Poisson distribution for a mean strike incidence of 8 per year is shown below in Figure 1. This shows the number of years, in each 100-year period, which will experience a certain number of strikes to the line per year. This shows that, in any particular year, we might expect anywhere from zero to twenty strikes to hit the line, with five to ten being most probable. A year with fifteen strikes has only a 1% probability.

These data can also be shown as a cumulative curve, that is the percentage of years in which the number of strikes will be less than a stated value. When the actual line data are compared with the cumulative data, it can be seen that they fit reasonably well for such a small sample (Figure 2).

The major lesson from this illustration is that there is a large variability in the number of lightning strikes from year to year, and it is not likely to depend as much on any small changes in local flash density as on the non-predictable statistical variation.

The problem is that human nature is more likely to ascribe a definite cause to variations in strike numbers than to ascribe it to chance. The occurrence of a large number of strikes to a facility will, in my experience, set the engineers scurrying to find a solution, even though this may be inappropriate action.

Calculating the lightning risk to a facility accurately, but in particular taking note of the likely statistical variations, is fundamentally important for any lightning risk analysis.

Dr. Michael Stringfellow is Chief Scientist at PowerCET Corporation. You can contact him at mike_s@powercet.com.

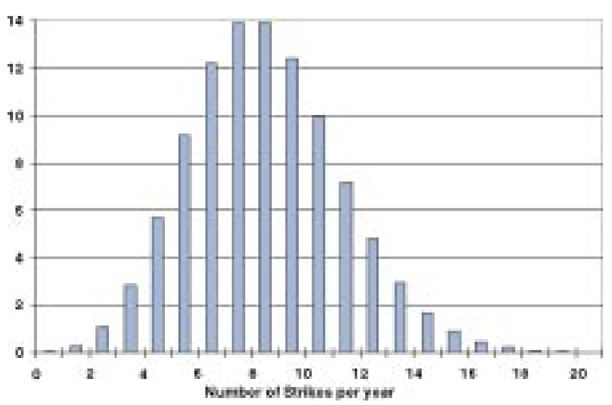


Figure 1.

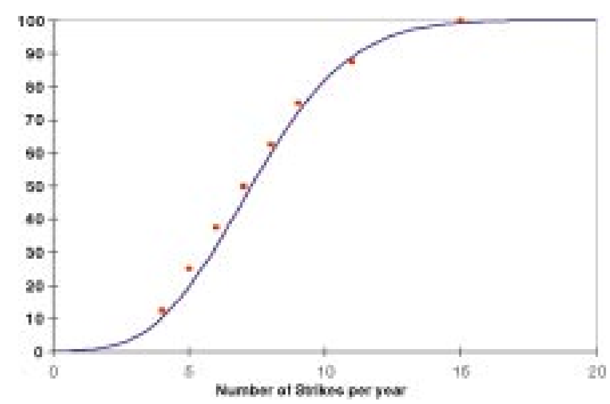


Figure 2.

Grounding

(continued from pg. 5)

Radio broadcasting also brought about developments in grounding technology. However, unlike DC or AC grounding systems, radio frequency (RF) grounding required low impedance at very high frequencies as well as low DC resistance. RF engineers learned to rely upon ground plane technology to assure ground wave propagation. Earth conductivity, the quality of grounding connections, noise in the grounding system and the implementation of ground plane technology all affected the propagation of radio signals.

These seemingly divergent grounding practices can lead to lively discussions when the topic of grounding arises. To a power engineer, grounding implies a low impedance method of referencing the AC system and ensuring rapid fault clearing through the use of a single point ground connection. To the telecommunications engineer, grounding means a low DC resistance between interconnected equipment and between the equipment and earth. To the RF engineer, grounding is a component in the process of signal propagation.

In the absence of solid data to drive a design decision, grounding efforts may be directed by past experience. When some equipment seems to work better with a ground wire from the chassis to a cold water pipe, then a natural inclination develops to install all equipment with a ground wire between the equipment chassis and a cold water pipe.

In fact, the combination of good intentions, misinformation and tradition creates many grounding problems. As an example, armed with the knowledge that skin effect limits the ability of small diameter wires to carry high frequency current and that equipment can "leak" high frequency current into the facility ground wire, a condition can arise in which a large gauge grounding wire will be installed between the chassis of a device and an isolated driven grounding rod to "control" the effects of interference. In fact, this practice can expose the equipment to momentary surges in current in the grounding of the device.

Worse yet, the normal AC grounding conductor may be abandoned in favor of a totally "isolated grounding system." The fact that this practice violates National Electrical Code does not deter the determined practitioners of "voodoo" grounding.

When contention between varying grounding practices occurs, then designs which follow the National Electrical Code must prevail. Equipment installations must be safe. Ignoring the code to achieve any perceived operational benefit cannot be condoned.

Tom Shaughnessy is Vice President of PowerCET Corporation. You can contact him at tom_s@powercet.com.