PQ CONNECTION™
Your Power Quality News Source
Vol. 1 No. 3 Spring 2001

PQ Hotline offers energy consulting for customers

Free Power Quality, Energy Management and Distributed Generation consulting

Cutler-Hammer's highly-touted advanced product application support 800 number has been expanded to include a special PQ Hotline option to obtain information on power quality, energy management and distributed generation issues.

"Until now, most of these types of calls have come to various people within Cutler-Hammer, including product managers, product specialists, sales and administrative people, etc.", said Power Quality Team Leader Dan Carnovale. "However, many of these calls are system-related and the person initially receiving the call may not be able to fully respond to our customers' needs and will have to pass the call along to someone else. Worst case, the call recipient may not fully understand the caller's need and therefore won't know to whom to forward the call. This is very frustrating and time-consuming for our customers and our sales force."

By directing the callers to the PQ Hotline, and staffing the line with people who more thoroughly understand power quality, energy management and distributed generation issues, customers are more likely to get their questions answered more promptly. "We want customers to get appropriate answers in the most timely manner," Carnovale said. "Even if the hotline personnel doesn't have all the answers, they're in the best position to know who will, and can either properly transfer a call or have the right person contact them by phone, email or in person, depending on the situation. It's a more efficient and effective way to help our customers, which is why we're implementing this hotline as a no-charge, value-added service for our customers. It's just one more service that helps define us as power quality and reliability solution experts."

The calls will be logged in a central database and will help Cutler-Hammer identify and track the issues that are asked about most frequently. Examples of anticipated question topics include system grounding, harmonics, surge protection, transfer switches, distributed generation, monitoring, power factor penalties, demand charges, voltage variations, etc.

Russ Barss, marketing manager for the Power Quality Group cited an example of how the PQ Hotline can help a customer whose equipment was struck by lightning. "By calling the number, a customer can find out what steps to take in the emergency," Barss explained. " Or if a customer called concerning harmonic problems, hotline personnel will be able to walk him through the solution. With the PQ Hotline, we have a streamlined process in place that will make Cutler-Hammer significantly more responsive."

Call the PQ Hotline for Power Quality and Advanced Products Application Support: 1.800.809.2772

Call the PQ Hotline for Power Quality and Advanced Products Application Support: 1.800.809.2772

OPTION 1:	Power Quality or Power Management Products. [effective April 15, 2001]	
SUBMENU:	OPTION 1	IQ metering devices, protective relays and PowerNet software and hardware
	OPTION 2.	Power Quality related applications, problems and troubleshooting
OPTION 2:	Limit switches, proximity and photoelectric sensors	
OPTION 3:	Durant product lines (counters, temperature controllers, digital panel meters and solid-state relays)	
OPTION 4:	Solid state reduced voltage motor starters and adjustable frequency drives	
OPTION 5:	Operator interface products (Panelmate) and industrial pc products (D700 line)	
OPTION 6:	Programmable controllers (PLCs) and Device Net Hardware and Software	

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FEATURE

Data Center reliability strengthened through environmental and power system audits

By Dan Carnovale, Ron Quade and Ron Thompson of Cutler-Hammer, and Jason Squitieri of Worldwide Environmental Services

Corporate headquarters, banks, credit card processing facilities, stock transfer centers, internet-based organizations – these and similar companies with whom customers have entrusted financial and proprietary information, securities and money rely on the accurate, dependable, secure and prompt storage and retrieval of data.

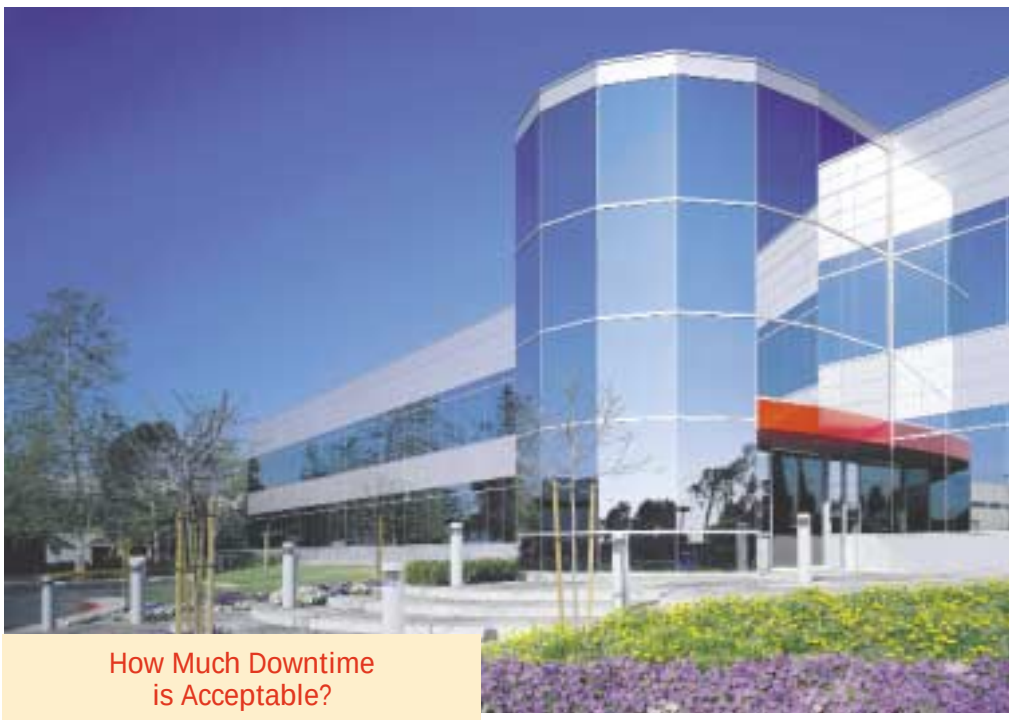
For these companies, maintaining an environmentally sound Data Center supported by uncompromised power quality is a critical business need. Even the briefest of power interruptions can cause the irretrievable loss of company and customer data, resulting in the loss of millions of dollars and customer trust (see inset graphic).

This article will provide a brief overview of the importance of Data Center environmental and power quality reliability and basic fundamentals of power system/environmental audits.

Why should I have Data Center power system and environmental audits?

Data Centers are the hub of many critical business applications. Designing, building, utilizing and leasing Data Center facilities requires a major corporate investment and can justifiably produce a significant square-foot lease revenue stream. Businesses can own Data Center facilities for their own business use and/or as a leased space investment that provides IT alternatives for restructured companies choosing to focus on their core competencies. For example, an average 60,000 square foot Data Center typically costs (or can generate as rental income) upwards of $250 sq/ft per month or more, for guaranteed functionality and reliability. Thus, significant rental income – in this instance $15 million a month! – is forfeited if lease customers' business applications are disrupted. And the loss of rent may be insignificant compared to the damage incurred to businesses who relied on the Data Center's functionality.

Therefore, given the critical operational reliability required of a business' Data Center, maintaining its power system and environment is not only an excellent, cost-effective investment but a necessity. By performing a comprehensive joint audit, supporting yearly testing of switchgear and other power system equipment, and utilizing a building monitoring system, Data Centers can continue to perform at peak operating levels.



How Much Downtime is Acceptable?

Reliability	Avg Disruption/Year
99%	88 hours
99.9%	8.8 hours
99.99%	0.88 hours
99.999%	5.3 minutes
99.9999%	32 seconds
99.99999%	3.2 seconds

Each additional "9" increases reliability & facility uptime.... improving productivity

The recommended Power Quality solution will depend upon the required uptime!

- Data centers = $$$$$
- Industrial Process = $$$
- Retail Facility = $$
- Residential = $

Environmental Audits

Designing and maintaining a proper Data Center environment can prevent equipment overheating or contamination, which could result in degraded hardware performance or failures. Environmental audits evaluate climate control factors, including air distribution and ventilation and temperature and relative humidity variations and contamination issues (among many other factors). Any of these can hinder the effective operation of sensitive Data Center equipment, and can decrease the Mean Time Between Failures (MTBF), an important measurement of uptime and reliability. A properly performed environmental audit can locate potential problems that might later be blamed on faulty equipment or poor power quality, thereby also optimizing the effect of a power system audit.

Power System Audits

Data Center power systems should be designed with redundant power sources and utilize reliable equipment. The main objective of a power system audit is to examine the existing power infrastructure to determine the general quality of power being provided to the data processing equipment and to identify any specific power issues – "weak links" – that may have an adverse effect on the hardware.

Visual inspection of Data Center equipment is a key element of the audit. Power systems supplying the Data Center typically

include some or all of the following:

- Multiple Utility Feeder
- Main Service Transformer(s)
- Main Switchgear
- Transient Voltage Surge Suppression
- Automatic Transfer Switch (ATS)
- Generator(s)
- UPS(s)
- Power Distribution Units (PDU)
- Signal Reference Grid (SRG)

A basic power system audit will visually observe and test numerous elements, including:

- Special grounding requirements – Data Centers contain sophisticated and sensitive power loads and special grounding is critical to ensure proper data system operation.
- Cable Management – Power and data cables should not be intertwined, coiled or jumbled together as this can generate electrical noise or Electro-Magnetic Interference (EMI), either of which can interfere with data transfer.
- Building Monitoring System (BMS) – The BMS is evaluated based on the ability to trend conditions to help identify the sources of problems, or to identify potential problems before they have an adverse impact on hardware operations.
- Switchgear Maintenance and Equipment Testing – Regular maintenance and cleaning of switchgear will help prevent insulation breakdown and operation failure of the trip mechanism on circuit breakers. Periodic electrical testing will determine the amount of insulation breakdown that has occurred on the breakers and switchboard and contact resistance between each pole inside a breaker. Infrared scans are performed to locate problems before they become serious. In addition, regular testing should be performed on all critical electrical equipment including generators, transfer switches batteries, UPSs, and transformers.

In addition to the previous tests, a comprehensive power system audit also monitors voltage, current and harmonics readings.

Cutler-Hammer and Worldwide Environmental Services– a winning team for Data Center audits

In May of 2000, Cutler-Hammer Engineering Services partnered with Worldwide Environmental Services (WES) to perform environmental and power quality audits at major Data Centers across the United States. To date, the team has performed more than 65 audits.

The partnership fulfills a customer need for optimizing the power reliability of critical business functions. The union brings together Cutler-Hammer's expertise in assessing power quality issues for utility, industrial and commercial customers with WES' 20+-year experience in serving the data processing industry as the world's leading computer room environmental specialists. Together, they provide unparalleled personalized solutions to Data Center power quality and environmental issues. "We are extremely pleased to be able to team with WES," said Dan Carnovale, Cutler-Hammer Power Quality Team Leader. "Their vast array of technical resources solid network of industry partnerships and long-standing relationships with hardware and support product manufacturers and maintenance experts is a wonderful complement to our customer power quality services. This partnership provides an excellent full-service solution to the Data Center industry."

- Voltage Readings – The most common voltage problems found are sags and surges. Sags can be caused by the start-up of large units of equipment or utility equipment failures. Surges are typically caused by large units of equipment switching off, lightning, or by utility capacitors switching on. Utility-generated surges will be diverted by surge protection devices at the service entrance if TVSS equipment is in use.
- Current Readings – Current imbalances are typically caused by the uneven distribution of room loads across the phases. Current imbalance can cause transformer overheating, and in the most severe instances can cause delaminating of transformer windings, shortening the life-span of the transformer.
- Harmonics Readings – Harmonics problems can typically be related directly to the equipment in the room and occur while all equipment is functioning properly. They can contribute to overheating and/or premature failure of conductors, transformers and breakers.

How is the power system audit performed?

Visual observations of the site and interviews with site personnel, consultants, and manufacturers provide the basis of the audit. Measurements are taken at strategically chosen points along the power system, which either represent the condition of the system or the reliability of the power for the equipment being tested. Measurements taken during the site visit are summarized and evaluated to help identify any problem areas.

Environmental and Power System Audit recommendation parameters

Once the data is retrieved and analyzed, the environmental and power system audit will specify a number of recommendations which may touch on:

- System design and safety issues
- Equipment and/or procedure deficiencies or enhancements
- Grounding concerns and design recommendations
- Switchgear maintenance issues
- Excessive harmonic distortion or other waveform abnormalities
- In-room temperature & relative humidity
- Environmental support equipment
- Air distribution efficiency
- Hardware design & configuration
- Contaminant levels and sources
- Perimeter exposures

Summary

Maintaining reliable corporate headquarter, bank, credit card processing, stock transfer and internet-based companies' Data Centers is a critical business need. Even the briefest of power interruptions can cause the irretrievable loss of company and customer data, resulting in the loss of millions of dollars and customer trust.

Maintaining the Data Center's power system and environment is not only an excellent, cost-effective investment but a necessity. By performing a comprehensive joint audit and yearly testing, Data Centers can continue to perform at peak operating levels, reducing the risk of data loss, equipment failure and downtime.

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Cutler-Hammer

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Environmental Audits

Environmental audits for Data Centers, which evaluate climate control factors, including air distribution and ventilation and temperature and relative humidity variations and contamination issues, can degrade hardware performance and affect uptime. A properly performed environmental audit can also optimize the effect of a power system audit.

Power System Audits

Redundant power supplies and reliable equipment are critical to the effective operation of Data Centers. A power system audit examines the existing power infrastructure and identifies any "weak links" that may have an adverse effect on the hardware.

Visual inspection of Data Center equipment is a key element of the audit. A basic power system audit will visually observe and test numerous elements, including special grounding requirements such as Signal Reference Grids (SRGs) which enhances the reliability of signal transfer between interconnected equipment by reducing common mode electrical noise, which can cause data transfer problems. Proper management of power and data cables will prevent electrical noise or Electro-Magnetic Interference (EMI), either of which can interfere with data transfer. Building Monitoring System (BMS) evaluations track the ability to trend conditions to help identify the sources of problems, or to identify potential problems before they have an adverse impact on hardware operations. Regular maintenance and cleaning of switchgear will help prevent insulation breakdown and operation failure of the trip mechanism on circuit breakers. Infrared scans are performed to locate problems before they become serious. In addition, regular testing should be performed on generators, transfer switch batteries, UPSs, and transformers.

Once the data is retrieved and analyzed, the environmental and power system audit will specify a number of recommendations.

For more information on Data Center environmental and power system audits, contact Dan Carnovale, Cutler-Hammer at 724.779.5843 or carnodj@ch.etn.com

For more information on Worldwide Environmental Services, please visit their web site at www.wes.net.

A Powerful Team: Cutler-Hammer and ICONICS

Continually searching for ways to better serve customers, Cutler-Hammer has signed a significant licensing agreement with ICONICS, Inc., manufacturer of GENESIS32 PC-based software. This covenant enables Cutler-Hammer to provide any of the ICONICS PC-based software solutions, including the flagship GENESIS32 and extending to the web browser, Windows CE and Pocket PC products.

The GENESIS32 bundle consists of OPC compliant HMI/SCADA software applications, including GraphWorx32 for drawing and animation; TrendWorx32 for real-time trending, historical data logging, reporting and analysis; AlarmWorx32 for distributed enterprise-wide alarming and events management; and WebHMI for OPC and visualization information delivered to any PC running Microsoft's Internet Explorer.

When integrated with the PowerNet Power Management System, the GENESIS32 bundle will provide improved graphics capabilities and information dissemination via the web for panelboard and switchboard systems. Cutler-Hammer Engineering Services will use the ICONICS technologies to provide lower cost diagnostics and information management solutions. PanelMate users equipped with the ICONICS products can view manufacturing information over the web.

To learn more, visit www.ch.cutler-hammer.com/pmp, or call your local Power Management Sales Manager or Cutler-Hammer ESS contact.

New Portable IQ Analyzer 6600

Introducing the new and improved Portable IQ Analyzer. The portable unit is based upon the powerful IQ Analyzer 6600 power quality meter. The 6600 provides the ability to store a wide variety of energy, trend and waveform data in nonvolatile memory for downloading and analysis.

Some of the improvements to the Portable 6600 include a battery power supply that enables the unit to operate up to three hours without AC input. This will enable the user to accurately capture sag and outage information. INCOM and RS-232 communication are both standard with the new 6600 portable unit. The INCOM communications allow the portable to be networked into an existing PowerNet system, while the RS-232 interface allows easy connection to a PC.

The Portable IQ Analyzer works with both PowerNet and PowerPort software. PowerPort software can be downloaded directly from the Internet for free and provides an easy to use configuration and monitoring interface.

Order catalog number IQA6610PORTI from your local Cutler-Hammer distributor.

FEATURE

Cutler-Hammer

Protecting critical equipment from voltage sags saves time and money

Determine how your equipment will respond to voltage sags and short-term interruptions. Applying cost-effective solutions to your power quality problems can save you significant and unnecessary costs and downtime..

The SRT is the first power conditioner to incorporate technology that corrects voltage sags and maintains uptime and productivity.

You awake from a restful night's sleep only to find that your alarm clock is flashing 12:00 due to an overnight electrical storm – and you're late for work. As if that isn't a bad enough way to start your day, when you arrive at work, you're told that five of the 250 HP drives on the process line have tripped because of the storm. The resulting three-hour shutdown cost your company hundreds of thousands in revenue. And your day has just begun.

You blame your misfortune on the power "going out," and assume it was an event outside of your control. However, 95% of power-related equipment problems aren't caused by a complete loss of power (i.e., the voltage doesn't actually drop to zero). Rather, the voltage is temporarily reduced to a level at which the equipment cannot perform properly, which causes the equipment to malfunction. This is called a voltage sag, the most common and costly power quality problem according to a comprehensive study performed by the Electric Power Research Institute (EPRI).

For electrical equipment to run properly, or at all, it requires a continuous power supply within designed tolerances. Depending on the equipment specifications, some reductions in the voltage level may be tolerated for a specified duration, but rarely will the operations manual tell you all the parameters under which the equipment is likely to fail. So how can you precisely determine how your equipment will respond to voltage sags and short-term interruptions, and ensure their continued operation?

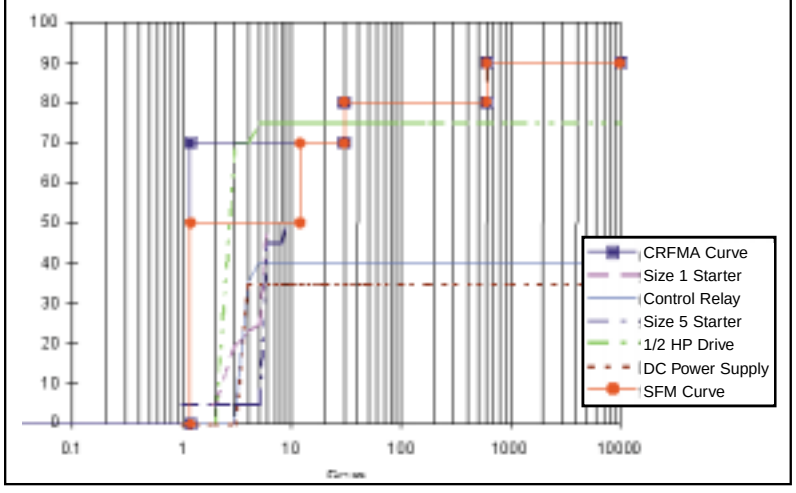
(1) Test the equipment, and/or

(2) Purchase products designed to prevent voltage sag equipment failures

Equipment Affected by Voltage Sags and Interruptions

Equipment	Problems
System/Personal Computers	Lockups, re-boot
PLC's, robotics	Garbled data, re-boot, lockups
Motor Drives (AC/DC)	Trip, slow down
Motor Contactors	Chatter, open
Lighting	
HID	Off
Incandescent	Flicker

Voltage Tolerance Testing



Equipment testing standards

Every electrical or electronic component has a specific tolerance curve from which it cannot deviate. However, many engineers and most equipment manufacturers mistakenly specify sensitive equipment tolerances as a single value – typically a voltage level or a single voltage and time. Sometimes no values are given. Therefore, the burden of determining the tolerance is left to you.

Today there is an understanding of the recommended input voltage minimums and maximums, and the reasons why voltage aberrations occur. Three standards have been developed for equipment manufacturers to test their equipment for voltage sag tolerance:

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- The Computer Business Equipment Manufacturers Association (CBEMA) Curve (recently revised and called the "new" CBEMA Curve or Information Technology Industry Council – ITIC Curve) – applicable to 120/240 V power supplies for computer and business equipment.
- SEMI F47-0999 – applicable for semiconductor processing equipment.
- IEC Voltage immunity testing (IEC 61000-4-11) – applicable European Standard

Testing against the standards with the help of power electronic simulators will determine your equipment tolerances. It will arm you with the information you need to make appropriate and cost-effective decisions that can prevent costly equipment malfunctions.

Testing under normal operating conditions with power electronic simulators provides accurate test results

The primary purpose of testing is to understand how low voltage equipment operates under fluctuating conditions that may occur on the power system. The best way to accurately determine tolerances is to simulate voltage variations with the aid of a power electronic simulator (see inset box) while the equipment under test (EUT) is in its normal operating state. If an AC drive is tested, for example, the normal operating speed and load should be set. If normal operation requires a range of speeds and loads, the worst condition should be tested. False conclusions will be reached if the drive is unloaded or lightly loaded during the test.

Power Electronic Simulator

Power electronic simulators have been available for many years in various forms for testing relays and other equipment but have recently been refined to test equipment against voltage variation standards (IEC standards, for example). The simulator includes an input section, a controller section, a power amplifier section and an output section. The simulators are software driven and allow the user to program the output voltage of a power amplifier of variable size to generate an arbitrary waveform. The user interface is either a computer connected via communications port to the controller or the instrument control knobs and keypad located on the front of the controller.

The ability of a plant to ride through voltage sags can have a significant impact on operations and competitiveness. In the United States, voltage sags cost billions of dollars in lost production, interruption, damaged materials, and retooling. In addition, sags can cause:

- **Increased operating costs**
- **The need for product reworks**
- **Safety hazards**
- **Equipment damage and/or failure**
- **Reduced product quality**
- **Increased clean-up**
- **Additional labor costs**
- **Increased scrap material**
- **Costs associated with investigation into the problem**

Analyzing the test results

Within a certain range, specific equipment will malfunction, each at a different level. The testing will reveal the order of susceptibility. From a system standpoint, the piece of equipment with the lowest acceptable retained voltage at a specific duration is the least sensitive to a voltage sag.

As a general rule of thumb, the test result is positive if the equipment shows its immunity, for the duration of the application of the test, and at the end of the tests the EUT fulfills the functional requirements established in the technical specification. A sample plot for several pieces of equipment is shown on the previous page.

Finding the weak link in a power system

When a system of equipment is tested and the "weak-link" curve is determined, it should be removed, "jumpered out," or powered from an alternate source and the test should be repeated to determine the next level of tolerance.

Preventive solutions supplied by Cutler-Hammer

One of the best, most cost-effective ways to deal with potential equipment misoperation due to power quality problems is to implement a preventive sag correction and voltage regulation solution: Cutler-Hammer's **Sag Ride Through (SRT) Power Conditioner** and/or **Electronic Voltage Regulator (EVR) Tap Changer.**

The **SRT** is a series connected, voltage compensation device that corrects voltage sags and maintains uptime and productivity. It operates in bypass mode and continuously monitors input voltage. When a sag disturbance is detected, the unit reacts in 2 milliseconds (sub-cycle) and electronically synthesizes the voltage required to correct the sag. The series connected transformer produces a clean stabilized output.

By correcting deep sags down to 30% of nominal (a 70% reduction), the SRT provides protection for sensitive downstream loads. It ensures improved operating productivity not possible with traditional tap switching or ferroresonant technologies, providing a tremendous return on your investment.

The **EVR** is designed to meet the needs of customers who experience voltage regulation problems due to brownout conditions or poor utility regulation. Based on the voltage input, the EVR automatically activates the appropriate transformer tap to maintain a consistent level of voltage output.

Dan Carnovale, Power Quality Team Leader noted, "the SRT is ideal for short duration events like voltage sags, and the EVR is very effective where there is poor utility voltage regulation, including longer duration events such as brownouts. There are numerous advantages to utilizing an SRT compared to the significantly more expensive Uninterruptible Power Supply (UPS) solutions. The SRT takes care of 95% of typical voltage variation problems faced by customers, it's two to four times less expensive than UPS, and it does not require batteries, cooling, or maintenance."

If you want to ensure your power quality, reliability and operating productivity, call your local Cutler-Hammer representative for information on obtaining equipment testing and cost-effective voltage sag correction and regulation solutions. To identify your local representative, please call 1-800-809-2772 and select option #1.

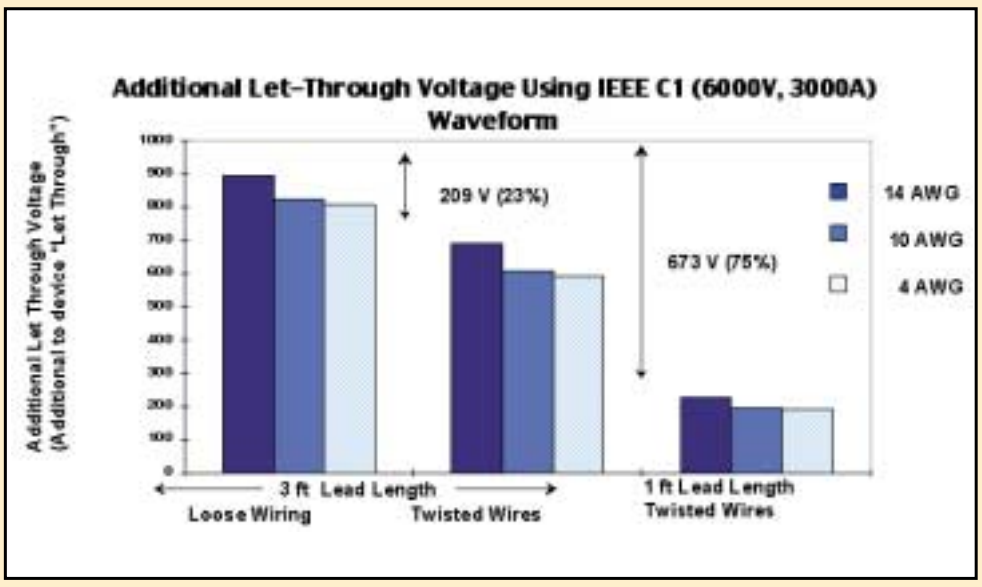
ASK THE EXPERT

Cutler-Hammer

Questions and Answers

Q What are the guidelines and calculations to determine the impact of internal wiring (Inductive and Capacitive) on a surge?

A The most important guideline for TVSS protection is lead length. For every inch of lead length, assume that you add 15-25V of let-through voltage. This means that if you expect the device to clamp at 400 V and the TVSS lead length is 2 feet longer than it should be, the let-through may be 1000 V! Keep in mind that the TVSSs are tested with a standard lead length of 16". As you add more inductance, the TVSS becomes ineffective. As you try to protect against high frequencies and increase the inductance, you dramatically increase the impedance. Most people use the lead length that we provide but our recommendation is to cut the lead as short as possible and make the wires as straight as possible. See graphic to the right. Twisting the wires, making the wires as straight as possible, and making the wire size larger helps but not nearly as much as making the leads as short as possible. For this reason, we now mount TVSSs directly to the panel board. Today, the vast majority of TVSSs sold by Cutler-Hammer are integrated units.



Q I measured the current into my capacitor bank with a Fluke 41B harmonic analyzer and the harmonic current distortion was very high (especially the 7th harmonic). Do capacitors generate harmonic distortions?

A No, capacitors do not generate harmonic distortions. The current into a capacitor would be linear (reflective of the 60 Hz voltage waveform) for a power system without harmonic sources (such as drives, switched mode power supplies, rectifiers, etc). Capacitors can "tune" a power system to amplify harmonics from other sources, however. When capacitors are added to a system they often appear to cause harmonics but they are really just amplifying harmonics that were already there. Harmonics into a capacitor are often elevated because of one of two types of harmonic resonance. Parallel resonance results in elevated harmonic current and voltage distortion, and series resonance results in elevated current distortion. Either resonant condition can result in capacitor damage or prematurely blown fuses. In your situation, the capacitor that was placed on your system is either series or parallel resonant near the 7th harmonic and you have some source(s) of 7th harmonic current on your power system (for example, variable frequency drives).

Q We have a question concerning VFD/ground current for a New York City wastewater plant. Ground current was monitored at the output of a VFD during factory tests and we do not understand and have not clearly been told why this is so. Is this a problem or not? Ground current has been monitored on a Mulitlin relay on some of the VFD's but not all (ranging from 0-2A). Is the ground current a normal occurrence?

A The instantaneous difference between the 3 phase voltages of the PWM switching at the carrier frequency, creates a residual voltage with respect to ground. The perceived ground current is typical of PWM output VFDs and is the result of these residual voltages driving current to the ground through the distributed capacitance of the system (cables, insulation of the motor, etc.). It is also likely that you could have some current measured with your motor protection relay, which may or may not be within the frequency range of the capability of the relay metering circuits (this current may be in the 1-5 kHz range). As the voltage builds up on the insulation and then discharges, you will see bursts of high frequency current.

The fact that this current approaches 2A is unusual, but to actually quantify the real value and frequencies involved, it should be measured with an oscilloscope. These currents may also become a problem if they are discharged across the bearings in motors, causing bearing "fluting." If you are replacing motor bearings more frequently than the normal 3-5 year replacement schedule, you should consider corrective action, which may include conductive grease or insulated bearings.

We encourage you to submit your questions and/or case studies. If your submission is published, you will receive a Home Surge Protection Package. Write to:
PQ Connection™, Cutler-Hammer, 1000 Cherrington Parkway, Moon Township, PA 15108 U.S.A.

Cutler-Hammer

2001 Power Quality Training Sessions

Class Name	Start Date	Duration (days)	Location
Power Quality and Grounding	01-May	4	Pittsburgh
Electrical Equipment Maintenance	08-May	4	Caracas
Electrical Safety	10-May	1	Los Angeles
Distribution Systems Analysis	15-May	4	Atlanta
Protection and Coordinatiion	29-May	4	Toronto
Power Quality Monitoring	05-Jun	2	Pittsburgh
Electrical Equipment Maintenance	24-Jul	4	Pittsburgh
Protective Relay Application	21-Aug	4	Margarita
Electrical Safety	06-Sep	1	Atlanta
Protection and Coordinatiion	25-Sep	4	Pittsburgh
Distribution Systems Analysis	02-Oct	4	Houston
Maintenance of Ampgard Starters	16-Oct	2	Asheville
Protection and Coordination	16-Oct	4	Puerto La Cruz
Power Quality Monitoring	23-Oct	2	Pittsburgh
Electrical Equipment Maintenance	06-Nov	4	Los Angeles
Protective Relay Application	13-Nov	4	Pittsburgh
Electrical Safety	27-Nov	1	Houston
Power Quality and Grounding	04-Dec	4	Pittsburgh

To register please call 1-800-809-2772 and select option #1.

Future Issues

We will continue to include “Ask the Expert” in upcoming issues and we encourage you to submit power quality questions or comments. Please fax your questions to (403) 717-0579 or e-mail chsurge@ch.etn.com, attention “Questions for the Power Quality Expert”.

To Subscribe:

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