

## Welcome to PQ Connection

Power Quality continues to be an important topic in the electrical industry. Our customers are facing a bombardment of new products and services to provide clean power in the most cost-effective manner.

One recent survey by EC&M magazine (1998) found that 68% of engineers state that "solving Power Quality issues is a very important challenge". The challenge includes how to build an effective Power Quality strategy and how to integrate various technologies together into a reliable system.

To help professionals keep abreast of the dynamic changes in the power quality industry, Cutler-Hammer has introduced the "PQ Connection" newsletter—a collaborative effort from our power quality team of

application engineers and technical specialists. Our objective is to include valuable information on application tips, changes to UL or IEEE standards, case studies and product announcements.

Cutler-Hammer has one of the largest Power Quality teams. Our expertise includes Power System Engineers, Product/System Application Engineers, and we are leading research efforts into new power quality technologies. Call your local Cutler-Hammer office for more information on our range of electrical and automation solutions.

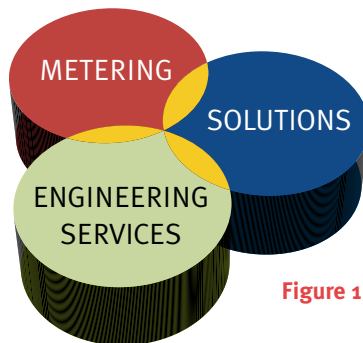


Figure 1

Figure 1: Cutler-Hammer's Complete Solution

### P.Q. METERING:

- Data event capture
- Voltage disturbances
- Harmonic content
- Facility wide power management

### P.Q. ENGINEERING SERVICES:

- Site surveys, monitoring and evaluations
- Problem solving
- Independent assessment
- Power system studies

### P.Q. SOLUTIONS:

- Surge Protection (AC, DC and datacom protection)
- Powerline Filters (EMI/RFI)
- K Factor Transformers
- Automatic Transfer Switches
- Power Distribution Units
- Customized harmonic solutions ■

## P4P a huge success

*Cutler-Hammer offers creative approaches to power distribution productivity issues*

Over 2500 consulting engineers, industrial users, contractors and distributors attended Cutler-Hammer's twelve Power for Productivity (P4P) seminars held across the US. These seminars were an overwhelming success. Response to the "solution" based—rather than product focused—seminars was fantastic. Solutions to today's most pressing concerns for electrical distribution systems that require new levels of Power Quality, Energy Management, Reliability & Uptime, and Information and Systems Integration were discussed.



The second stage of P4P is local, condensed versions of these seminars. A Chicago Cutler-Hammer office recently hosted a series of technology updates during the first quarter of '99 as a follow up to the bigger P4P held last year. Local P4P's were held in both Oregon and New Jersey in the month of June. Over 5000 people are expected to attend the local P4P's.

"Power for Productivity isn't an event like the circus that comes to town once every three years, it's a continuous process to educate and discuss with our customers the latest technology solutions," says Bill Mortensen Industrial Segment Marketing Manager, Cutler-Hammer.

This summer P4P is expanding into Mexico City and Monterrey, Mexico using Spanish translated presentations. Following Mexico, the seminars will move into Costa Rica and Central America.

Call your local C-H sales engineer to set up or attend a local P4P in your area. Call 1-800-525-2000 for the nearest C-H sales office. ■

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## CASE STUDY

# High Resistance Grounding - Case Study: Marathon Oil Company

*Protecting Down-Hole Submersible Pumps and Motors from Damaging Fault Related Voltage Transients*

JILL REVOLT  
SEGMENT MARKETING MANAGER  
DAVE SHIPP  
ADVISORY ENGINEER

### Objective

Marathon Oil Company wanted to improve the life and reliability of their Electrical Submersible Pump (ESP) systems.

### Strategy

Apply High Resistance Grounding (HRG) units to the electrical system. This technology, proven effective in other industrial environments, reduces the unsafe and damaging overvoltage conditions that may occur under arcing ground fault conditions. The HRG unit can detect, identify, and control the ground fault.

What makes this technology so desirable to the application is that it does not necessarily have to take the ground fault system off-line. Once the HRG unit has detected and located the ground fault, Marathon would be able to evaluate the situation and determine the best course of corrective action. If the location of the fault is determined to be down-hole and not in a classified wellhead area, then the well could be run with the ground fault on it indefinitely.

### Results

Marathon applied HRG units to two wells on their Tchataba Marin platform located off the coast of Gabon, Africa. Six weeks after the installation of the HRG units, both wells experienced failures. Well #2 failed first, experiencing a phase to ground fault and then a phase to phase fault. The well operated for six hours with the phase to ground fault since the HRG unit was able to control the overvoltages.

Marathon production engineers pulled well #2 to find that a packer penetrator installation problem had caused the initial

ground fault. Further investigation indicated that after the original ground fault occurred, the HRG unit kept the system on line and operating until the phase to phase fault occurred. The motor, cable, and down-hole sensors were all undamaged and still functional. However, the motor was replaced with a spare as a precautionary measure.

While the work was being done on well #2, well #3 experienced the identical failure mode. Unfortunately, the HRG unit on well #3 was off-line at the time. Well #3 failed instantly since it did not have any protection from the ground fault induced overvoltages.

**“If both motors had burned, Marathon Oil would have spent another \$300K - \$400K”**

Immediately after finishing well #2, Marathon pulled well #3. The #3 motor was burned at the star point. The Phoenix down-hole sensing system was also destroyed. Marathon did not have a spare motor for well #3 so elected to rerun the motor pulled from the #2 well in #3.

At the time this document was written (six months later), there have been no additional problems with either well. Both ESP systems are running with the HRG units on line and producing approximately 10,000 bpd each.

### Technical Notes

Seventy percent of all faults start out as arcing ground faults. This can lead to transient overvoltages. When the overvoltage reaches about 700%, the system insulation breaks down.

High transient voltages can result in:

- Motor Failure
- Down-Hole Sensing Equipment Failure
- Cable Insulation Failure
- Penetrator Failure

The solution was to design a high resistance grounding (HRG) unit tailored to the specific needs of the petroleum industry. When an HRG unit is applied to an electrical system, you have the benefit of a ground protected system without necessarily impairing the continuity of service. When it is determined that there is a ground fault on the system, the HRG unit can alarm or, if desired, trip the system.

HGR technology is as close to an ungrounded system as you can get but without the negatives of an ungrounded system. The HRG unit was designed to handle up to 5kV. It can be applied to a delta or wye ungrounded three wire distribution systems.

Interface with Down-Hole Sensor Technology – when down-hole sensing equipment is utilized on a well, the Cutler-Hammer HRG unit can be equipped with customized signal blocker circuitry. This signal blocker keeps the down-hole sensor signal from erroneously flowing through the HRG unit’s ground connection and resulting in an incorrect alarm or trip condition. With the signal blocker circuitry to guard possible nuisance tripping, the down-hole sensing equipment can use the power conductors as a signal

path, thus eliminating the need for expensive dedicated control cable for a signal path.

### Conclusion

According to Keith Fangmeier, Advanced Senior Production Engineer for Marathon Oil Company, "Both systems were essentially the same except for the operation of the High Resistance Grounding units. I believe the HRG unit saved the motor on #2. ESP manufacturers are not fond of grounding ESP systems; but, in this case, Marathon may have saved a motor. More important than saving the motor was the rig time and transportation expenses in obtaining a new motor for #3. If both motors had burned, Marathon Oil would have spent another \$300K - \$400K." ■



Cutler-Hammer Engineering Services provides a full-range of on-site services including: Start-up Commissioning, Preventive and Predictive Maintenance, Power Systems Studies and Equipment Life extension.

## 1999 Training Program – Locations and Dates

### Power Quality and Grounding

Power Quality and Grounding is designed for engineers and others who are responsible for maintaining the reliable and efficient operation of industrial or institutional power systems.

#### Program Content:

- How power disturbances affect equipment
- Causes of interruptions, swell, sags, flicker, transients
- Reducing power disturbance problems
- Causes and symptoms of harmonic currents
- Correcting harmonic current problems
- Symptoms of ineffective grounding
- Grounding of power equipment, sensitive electronic equipment and power systems
- Related ANSI/IEEE UL, CBEMA, GE and IEC standards
- Hands-on practice using power analyzers

#### Dates:

Indianapolis, Indiana, August 31- September 3  
 Baltimore, Maryland, September 21-24  
 Toronto, Ontario, October 19-22  
 Pittsburgh, Pennsylvania, November 16-19

#### Tuition:

- \$1195 US for locations in the USA
- \$1495 Canadian for locations in Canada
- 10% discount for early registration (two weeks prior)

### Power Quality Monitoring

The Power Quality Monitoring program is designed for engineers and technicians who need to know how to identify power quality problems or perform measurements of sags, swells, voltage transients, harmonic distortion and voltage flicker.

#### Program Content:

- Power Quality fundamentals – disturbances, harmonics, example waveforms, equipment tolerances, CBEMA, IEEE 519, and IEC standards

- Practice session - Monitoring multi-cycle voltage variations
- Practice session – Build your own equipment tolerance diagram
- Practice session – Monitoring transients, subcycle disturbances and flicker
- Practice session – Monitoring harmonics
- Practice session – Evaluating power quality problems using power monitor data

#### Dates:

Pittsburgh, Pennsylvania, Aug. 10-11  
 Pittsburgh, Pennsylvania, Oct. 13-14

#### Tuition

- \$695 US for locations in the USA
- \$870 Canadian for locations in Canada
- 10% discount for early registration (two weeks prior)

To register or for more information, please call (724) 779-5840 or 1 (888) 436-1585





# PQ STANDARDS UPDATE



**GEORGE BOWDEN,  
P.ENG**  
PRODUCT LINE MANAGER,  
POWER QUALITY &  
PREDICTIVE MAINTENANCE

*Standards are continually changing and it is important to be aware of how these changes affect the power quality industry. To assist you, Cutler-Hammer has summarized some of the key changes in International standards, IEEE 519, and other relevant topics.*

## International Standards Update

■ There was a seminar/workshop held in Washington DC during the last week of January '99. It was held to discuss the U.S. position on IEC standards regarding harmonic limits for single-phase electronic equipment. Most participants believed the proposed limits similar to IEC 1000-3-2 were too stringent.

■ From now on you will notice that the 1000 designation on the IEC standards is being replaced by the 61000 designation.

■ Other standards of note

IEC 61000-3-4; three phase equipment up to 75 amps, has or soon will be published.

IEC 61000-3-6, this is a parallel document to IEEE 519 evaluating harmonic compliance, and is available from the IEC.

61000-4-7 this is the main IEC document detailing measurement of harmonics, and has not been adopted in North America at this time.

■ EN 50160 is the Euronorm standard that defines utility HV, MV, & LV levels in EC countries. It details voltage regulation, and harmonic levels between different utilities selling and transporting power between EC countries. It does not include transients or flicker levels.

■ The UK has issued a new version of its standard, and the current reference is G5/4.

## Other standard groups of note (more on these groups in the next issue):-

■ Working Group P1433 Power Quality Definitions

■ Working Groups under P1159

■ P1159.1 Task Force on Recorder Qualification and Data Acquisition Requirements for Characterization of PQ Events

(Appropriate Sample Rate for event measured)

■ P1159.2 Task Force on Characterization of a Power Quality Event Given An Adequately Sampled Set of Digital Data Points

(Characterization of the Sampled Data)

■ P1159.3 Task Force on the Transfer of Power Quality Data

(Interchange data format)

P1346 – Electric Power System Compatibility with Electronic Process Equipment

P1509—Distribution Custom Power Task Force—Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV through 38 kV

P1453 – Flicker Task Force

P1531 – Harmonic Filter Task Force— Divided into 2 groups LV & MV/HV.

Single Phase Harmonics Task Force

The following groups are also working under the PES Harmonics Working Group

■ IEEE Harmonics Modeling and Simulation Task Force

■ Probabilistic Methods Task Force.

■ Interharmonics Task Force—a chapter on this subject has been developed for the latest draft of IEEE 519a.

A new task force to meet for the first time at the PES Winter Power meeting on Active Filters. A chairman (Chuck Gougler) has been selected for this task force.

## New IEEE 519 Harmonic Limits on Power Systems

■ The current thinking is that the new document will remain a Recommended Practice – it will not progress to a standard.

■ The completion date has been pushed back to 2002.

■ The new document will not contain harmonic limits for individual pieces of equipment, or limits within facilities away from the PCC, as once thought.

■ This document will be co-sponsored by both the PES and the IAS groups.

■ The committee suggests a new column be added to the tables, recommending limits for interfaces at one kV or less.

■ Inclusion of limits on even harmonics still being discussed.

## P519A Task Force – Guide for Applying Harmonic Limits on Power Systems

The current draft (draft 6) is expected to be the last version before it goes to ballot. There is a possibility that a tutorial on 519A will be prepared for the next IEEE PES Winter Power Meeting. ■



# Documentation of Power System Disturbances at a Large Industrial Facility

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APPLICATION ENGINEER

LINDA HARRIS  
INDUSTRY MANAGER, UTILITY SEGMENT

This monitoring tip outlines uses of the Cutler-Hammer IQ Analyzer by a large chemical plant in the Southeastern United States. The IQ Analyzer is a fixed mounted power quality meter that offers fully functional metering, ANSI C12 revenue accuracy, harmonic parameters to the 50th harmonic including harmonic voltage and current magnitudes and phase angles, and system disturbance capabilities including the ability to capture waveforms. All waveforms shown are actual waveforms captured by the IQ Analyzer at the aforesaid facility.

Eight IQ Analyzers are located at the main 4160V switchgear. They are each located at the secondary of the 4 utility owned transformers providing 4160V to the facility. Thus, they are at the interface point between this industrial facility and its electric utility. This facility is electrically connected to its sister facility on the primary side of the utility transformer. Using data collected from the IQ Analyzer, we will show fault current behavior during a fault on the primary side of the utility transformer at the unmonitored sister facility. We will also show the effects of increased load on the voltage.

Figure 1. shows the effect on Phase A current and voltage of a major fault on the primary side of the utility transformer feeding the unmonitored sister facility. The IA current changes directions and back feeds to the fault location.

Figure 2. shows phase B current and voltage which do not change directions, thus we know that the fault occurred on Phase A.

Figure 1. also shows that some load was lost in the monitored facility due to the fault. Recorded time-stamped minimum and maximum current and voltage data (not included) shows the sequence of events of a second fault on the transformer physically adjacent to the previously faulted transformer. This data confirmed the sequence of events as described by witnesses to the explosions. Since, the two sister facilities were connected at the primary of their utility transformers, the monitored facility lost voltage after the second transformer faulted.

A second example of the use the IQ Analyzer as a fixed mounted power quality monitor involves recording of voltage sags. Voltage sags and swells are the most common of all power quality problems. The ability to record voltage sags and associated waveforms on a continuous basis greatly reduce time and effort in troubleshooting the cause and effect of these events.

Figure 3. illustrates a voltage sag probably due to starting of a large load down stream from the monitoring device.

Figure 4. illustrates a recorded voltage sag.

By utilizing fixed mounted power quality monitors such as the IQ Analyzer, this facility has the ability to constantly monitor its electrical distribution system for system disturbances, either before or at the point of utility delivery or in its own electrical distribution system. This saves time in evaluation of disturbances and money in increased production time, and produces more reliable answers and solutions. ■

Device 1, 10/15/96, 12:56:27.31

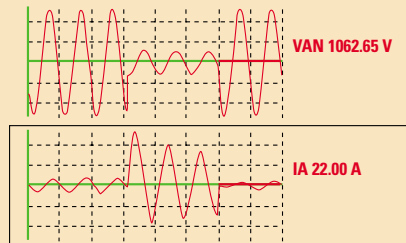


Figure 1

Device 1, 10/15/96, 12:56:27.31

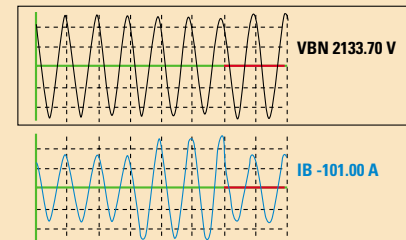


Figure 2

Device 7, 7/13/96, 17:55:42.28

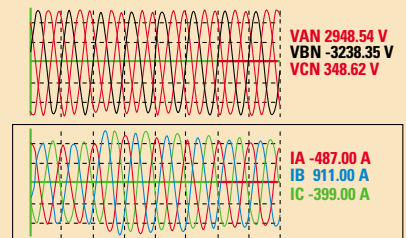


Figure 3

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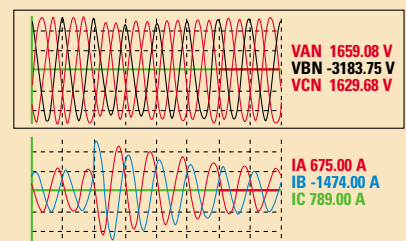
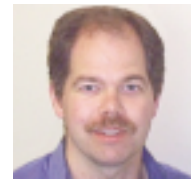


Figure 4



# FEATURE

## Specifying the Right Ratings for Surge Suppressors



**RUSS BARSS, P.ENG**  
PRODUCT LINE  
MANAGER, SURGE  
PRODUCTS



**JAMES FUNKE, P.ENG**  
CHIEF ENGINEER  
SURGE PRODUCTS

*The Key to Specifying the Right Suppressor is Understanding that the Amplitude of a Lightning Strike is Unrelated to a Power Line Surge.*

Let's jump to the bottom line: specifying surge suppressors with ratings above 250 kA per phase is overengineering that needlessly increases your clients' investment in electrical protection. It is analogous to specifying a 4/0 cable to feed a 20-amp outlet, or a 64-circuit loadcenter to supply a one-bedroom apartment.

Yet, and despite the obvious folly of such overengineering, some manufacturers of surge suppressors are recommending it, insisting that ratings of 500 kA, 800 kA, even one thousand kA are needed. They have ratcheted up the ratings during the past few years, arguing its validity by pointing out that lightning strikes of up to a thousand kA can, and do, impose those same amperages on facility wiring (untrue).

The continuous ratcheting raises other important questions: are lightning strikes carrying more energy now than in the past? (not that we know of), and at what rating will the ratcheting end? (when consultants and other specifiers say so).

### The Plain Truth About Lightning Strikes

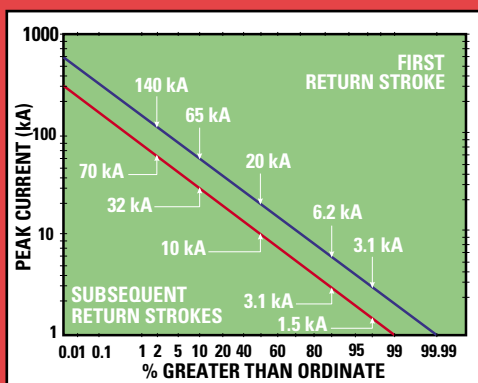
Lightning strikes are the flashes that jump between clouds and earth; their currents vary widely. Virtually all—99.98 percent by the best estimates—carry an initial current of less than 220 kA; about fifty percent of all strikes carry a current of less than 18 kA.

According to the IEEE, the amplitude of lightning strikes varies from a few kA, through the medium values of 20 kA, to the exceptional values (only 5 percent of all strikes) in excess of 100 kA (see Figure 1).

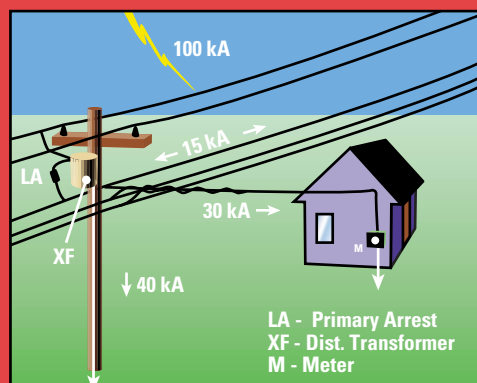
Regardless, the magnitude of strike currents is irrelevant when specifying surge suppressors. Why? Because when a strike hits a power line, service entrance, or building it follows the paths of least resistance. Most of its energy is shunted to ground through the power provider's arresters installed on distribution poles, other arresters installed at the facility's service entrance, the building's structural and plumbing systems, and lightning rods.

(see Figure 2) The remaining energy, by now a small fraction of the energy in the initial lightning strike, enters the facility's power system by inductance or capacitance. Several major conclusions can be drawn from these facts:

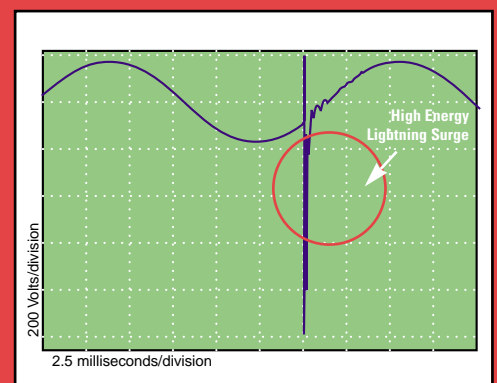
1. The induced or capacitive current creates a transient impulse (Fig.3) that lasts less than one-half cycle with a maximum amplitude of 20kV, 10kA (8x20 μs surge as recognized by IEEE 62.41).
2. BIL limitations prevent higher currents from traveling down conductors to valuable equipment, causing arcing. In fact, low voltage wiring (defined as fewer than 1000 volts by the IEEE) would have trouble carrying a combination wave of 20 kV, 10kA without exceeding 6000 V BIL ratings. Therefore it is impossible for the high current (ie > 500 kA) claimed by some surge suppression manufacturers to travel into a facility.



**Figure 1:** Distribution of Lightning Strike Current. Only .02 percent of all lightning strikes carry currents of 225 kA. The median amplitude is less than 20 kA.



**Figure 2:** A lightning strike will seek paths to ground according to the impedance of paths to ground according to the impedance of each path of parallel combination. The relative values shown on the diagram are arbitrary, selected to illustrate the concept.



**Figure 3:** Lightning can produce surges with high voltages and currents, but the duration of the surges is short, typically fewer than 100 μs.



### A Prudent Design Approach

A rational, deliberate approach to the design of a practical surge protection system must balance, simultaneously, at least four variables:

1. The frequency of lightning strikes (or, the degree of environmental hostility), depends heavily on geography, and is generally expressed as strikes/square km/year (see Figures 4a and 4b).
2. The amplitude of lightning strikes, which has already been addressed.
3. The degree of protection desired based on the integrity and sensitivities of the equipment to be protected, the characteristics of the electrical system, and the performance of surge protective devices, including...
4. The life expectancy of arresters/suppressors, which is directly related to the rating of the device and the frequency and amplitude of strikes.

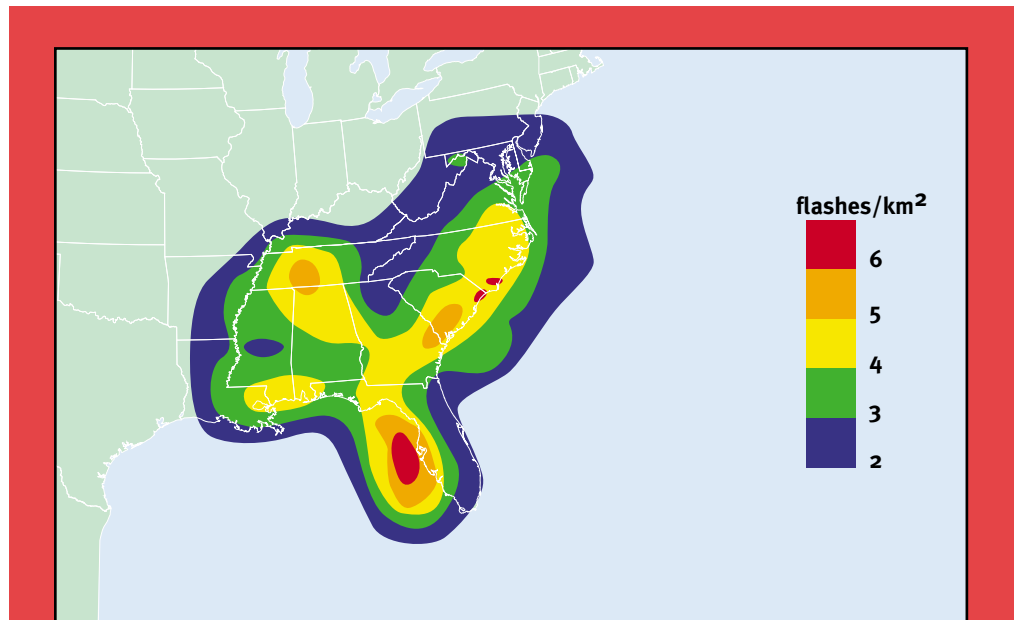
UL requires that facility surge suppressors in service entrance applications be tested to 10 kA per phase to assure safety and reliability. Yet, Cutler-Hammer recommends actual ratings from 50 kA up to 250 kA per phase. The reason is life expectancy, not added protection.

A service entrance suppressor will be subjected to thousands of surges of various magnitudes; each will shorten the life of the suppressor by various degrees. Statistical data indicate that suppressors installed in, say, Florida, the lightning capital of North America, and rated 250 kA per phase, can be expected to remain in service for 25 years or more, even longer in areas where lightning strikes are less frequent.

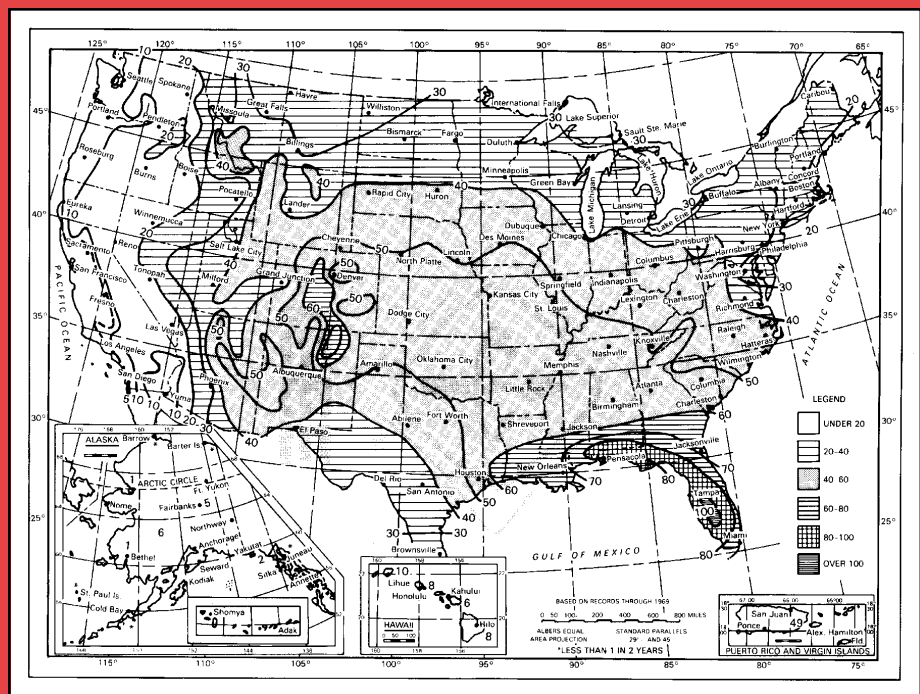
Failure of a suppressor is extremely rare, and is generally caused by a swell or temporary overvoltage (TOV) on the utility's power line, i.e., when the voltage on a 120 V line rises to 170 V or higher for short periods of time. Therefore, it's apparent that no engineering or other value is derived from ratings of suppressors that exceed 250 kA/phase.

### Conclusion: Specify Up To 250kA/Phase

There is absolutely no direct relationship between the amplitude of lightning strikes and the amplitude of surges—also called transient impulses—on power lines.



**Figure 4a:** The density of lightning strikes in the Eastern and Midwestern states varies widely from 6 km<sup>2</sup>/year in Central Florida, Coastal South Carolina, and South Central Tennessee to only 1 km<sup>2</sup>/year throughout most of the Midwest and Northeast.



**Figure 4b:** Exposure to lightning can be related to the number of thunderstorm days/year in a geographic area. The area just south of Tampa, Florida, is highest, at more than 100 thunderstorms/year, followed by the rest of Florida and a good part of the Southeastern United States. Suppressors of higher ratings should be specified in areas of higher densities, not because they offer greater protection, but because their service lives will be longer.

Surges can enter the facility's incoming electrical, telephone, and coaxial conductors, requiring that prudent design protect all three paths. Surge suppressors rated 250 kA per phase will protect AC power lines against all recorded lightning strikes, and

will remain in service for 25 years or longer even where lightning strikes are most frequent. Protection is not increased by specifying suppressors rated higher than 250 kA, but cost is, and facility owners will pay for protection that is unwarranted. ■

1 IEEE 62.41-1991. Reaffirmed 1996. 2 IEEE 62.41-1991, Appendix B, paragraph B1. 3 Surge and Temporary Over Voltage Protection Considerations for Remote and Wireless Telecommunications Sites, by Russell Bars and James Funke, Cutler-Hammer. 4 Orvill, R. E., Henderson, R.W., and Pyle, R. B. Lightning Flash Characteristics: 1987. Interim Report el-6413, August 1989, Electric Power Institute.



# NEW PRODUCT INFORMATION

## IQ Analyzer Combines an Easy-to-Use Meter and Powerful Analyzer for Optimum Power Quality

The IQ Analyzer serves as a complete solution for industrial, commercial and institutional facilities managers who need to monitor all aspects of their electrical distribution systems. One of the most user-friendly devices in its class, the device combines the precision of digital metering with the continuous, real-time monitoring and diagnostics capabilities of a state-of-the-art analyzer.

Data displays are hierarchically organized for easy, one-touch step-through, and include a built-in 'Help' utility which provides on-line user assistance. In addition to the pre-loaded standard screen formats, users can program two optional custom screens.

In its meter mode, the IQ Analyzer monitors a full range of system parameters including current, voltage, power (in watts, Vars or VA), energy utilization, demand, power factor, frequency and harmonic distortion parameters on % THD for both current and voltage phase angle, K-factor, CBEMA and Crest Factor.

In the analyzer mode, any of four optional analysis functions may be selected: trend analysis, harmonic analysis, event/alarm analysis and demand analysis. Within each function, various analytical operations can be performed, utilizing both real-time and historical data stored in the IQ Analyzer's non-volatile memory which can be accessed from the device without the use of additional software. ■



## Reflected Wave Trap extends motor life and increases production uptime

Cutler-Hammer introduces the Reflected Wave Trap (RWT), a patented motor-protection device for the drives industry that can be used universally on any manufacturer's VFD or motor. Reflected wave spikes occur when distances between drives and motors exceeds 50 feet. These spikes damage motor insulation, resulting in motor failure and operational downtime.



The RWT offers superior performance over existing motor-terminated or reactor-based technologies. With an easy to install, one-size-fits-all design, the RWT adapts to new and existing drive applications and does not require sizing to motor horsepower and voltage. Its high carrier frequency operates up to 12 kHz, compared to 2 to 6 kHz for other manufacturer's designs. Additionally, the RWT provides installation and operational flexibility with long lengths between the drive and motor – up to 750 feet (40° ambient) or 1000 feet (25° ambient). Its low surface temperature offers a high level of safety and extends the RWT's life expectancy. Maximum surface temperature in a 40°C environment is 90°C compared to other solutions that exceed 200°C.

The Reflected Wave Trap can be used with other Cutler-Hammer surge protection products as part of a facility-wide approach to reduce equipment downtime or damage from power disturbances. ■

## future issues:

In future issues, we will be adding the section "Ask the Expert" and encourage you to submit power quality questions or comments. Please fax your questions to (403) 717 0579 or e-mail [chsurge@ch.etn.com](mailto:chsurge@ch.etn.com), attention "Questions for the Power Quality Expert".

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## PQ CONNECTION™

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