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System Compatibility researchNEWS

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Special Edition: Tools for a Deregulated World

- *Without the right tools, power quality engineers can't be all that they can be (page 2).*
- *Engineers use simulation software and the "porto-sag" to demystify the effects of recloser-sequence sags (page 3).*
- *How long is too long? PEAC engineers look at the long-lead effect (page 4).*

Thomas Cooke, a PEAC laboratory technician, displays the circuit board for the Process Ride-Through Evaluation System, or porto-sag, now available to qualified EPRI-member utilities. The main components of the porto-sag consist of heavy-duty transistors, gate-driver circuits, contact relays, a data-acquisition module, and a laptop computer. External variable transformers, one for each phase of equipment voltage, control the depth of the sag delivered to the equipment.

'Porto-sag' evaluation system and services now available

Interest in the Process Ride-Through Evaluation System—a.k.a. the porto-sag—has led PEAC to build three three-phase models for use with EPRI-member utilities, with the possibility of others in the works.

First developed in the summer of 1995, the porto-sag is a diagnostic device that determines specific incompatibilities between industrial process equipment and the electrical environment. And as its name suggests, it's portable, a "mobile laboratory" according to one of its chief designers, PEAC engineer Doni Nastasi. The version of the porto-sag

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From the Editor

Gene Sitzlar
Editor

As if you didn't know, the entire electric utility industry is abuzz with the prospects of deregulation. Utilities are beefing up their power quality services to prepare for the inevitable vying for market share, for the inevitable fence-hopping and corporate mergers that may shift traditional service boundaries.

But before utilities get lean, mean, and greased for battle with each other, they must first address the enemy within their own fences: system incompatibility. Resolving system compatibility issues by identifying and addressing the causes and not merely treating the symptoms will help utilities maintain a loyal customer base.

Even as the price of kilowatt-hours seems to be the linchpin of competitive advantage, customers may be willing to pay a little more for premium power, justified by increased profits when equipment operates reliably.

In this issue, we bring you news about PEAC research, products, and services that can help whet your competitive edge in a world of deregulation. Power quality diagnostics, for example, has burgeoned into one of our most valued resources for electric utilities. On page two, Tom Key talks about the importance of using the new diagnostic tools available to power quality engineers who conduct house calls, which is one sure way to gain customer appreciation. In the realm of medicine, this notion may be considered obsolete, but in the realm of deregulated power, it's an implied obligation. I hope you enjoy reading about our tools, such as our Process Ride-Through Evaluation System, and the research and testing we have conducted since the last issue of our newsletter.

Field Findings

Using Our Tools of the Trade

by Tom Key, Technical Director

A plastics plant in Tennessee called the Tennessee Valley Authority through its local power distributor to understand and eliminate periodic tripping of a 400-horsepower AC induction motor. The motor, which was part of a large extruder, was protected by sensors in an electronic soft-starter. Alex Chomicki, a TVA power quality engineer, conducted a cursory investigation and discovered that the AC motor in the large extruder tripped only when a DC motor in a different, nearby extruder was heavily loaded. Based upon his experience, he immediately suspected three possible causes: a voltage unbalance, a controller malfunction, or an interaction with the DC drive that controlled the DC motor.

The soft-start protection circuit of the extruder was set to trip at a thirty-five percent current unbalance. However, initial voltage and current measurements at the AC motor denied Chomicki's voltage-unbalance hunch. The current was only six percent unbalanced, and the voltage was less than two percent unbalanced. Chomicki next looked at the waveform of the AC motor current with the oscilloscope built into his power quality monitor. He noticed a significant depression in one quarter of the cycle, which he attributed to an instantaneous change in current.

Measurements at the terminals of the DC drive indicated a normal steady-state RMS voltage. Measuring the current on one phase of the three-phase terminals revealed the uncharacteristic waveform shown in the figure below. Instead of the two-hump current characteristic of a DC drive, the current was significantly distorted. Measuring inside the DC drive, Steve Cook, a TVA power quality technician, found a blown fuse on one of the six silicon-controlled rectifiers. The manufacturer was called in to repair the drive.

Chomicki speculated that the additional harmonics caused by the missing SCR leg had created a resonance condition, which in turn caused the unusual waveform at the terminals of the AC motor. The unusual waveform at the terminals of the AC motor was causing the sensors in the electronic soft-starter to inaccurately measure the amount of current unbalance, resulting in a faulty trip. Once the DC drive was repaired, the current waveform at the AC motor appeared normal, and a fully loaded DC motor no longer tripped it.

In power quality monitoring, engineers are often biased by experience to look at certain things and dismiss others. By using the right equipment and taking comprehensive measurements at the right places, Chomicki was able to diagnose this rather complex problem and eliminate the most obvious culprits of motor tripping. The trick is to rely on our measurement tools when experience can't lead us to an easy answer.

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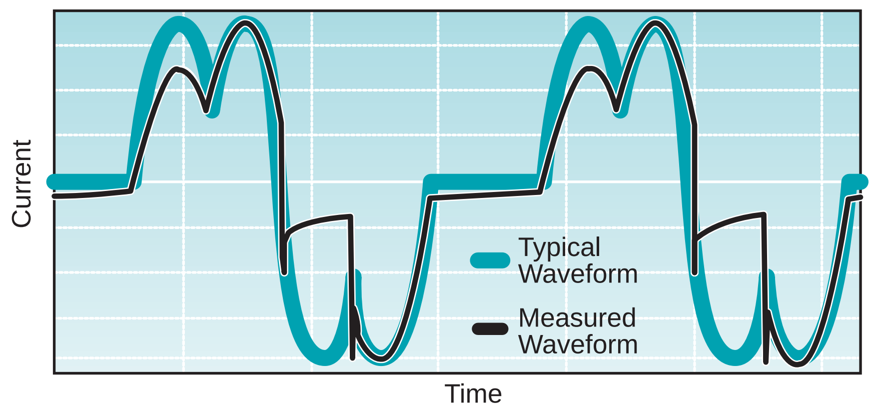

The current waveform measured at the DC drive was significantly different from the waveform that Chomicki expected—a double-hump characteristic of DC drives.

PORTO-SAG, from page 1

being assembled for utility use is a far cry from its predecessor. The original porto-sag nearly belied its name: It weighed several tons and had to be wheeled in on a trailer. But form eventually caught up to function. The device is now a mere 50 pounds of hardware controlled by a laptop computer.

The porto-sag works by plugging into process equipment—such as a printing press—and allowing power quality experts to simulate voltage sags and swells in the equipment's input voltage while the equipment operates. The whole process is closely monitored by computer software that controls the magnitude, phase angle, and duration of the sag or swell, all while recording up to sixteen process parameters.

Tests conducted with the new devices can be done under the guidance of experienced power quality engineers from PEAC's Power Quality Test Facility. "We made nearly thirty site-trips with the porto-sag last year—going everywhere from Seattle to Cleveland," said Nastasi. "Its capabilities became obvious pretty quickly, so we created a training program to help utilities use this diagnostic tool."

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Researchers study the effects of recloser-sequence sags

Reclosing circuit breakers, also called reclosers, automatically open and reclose to avoid blown fuses during temporary faults. A fault on a feeder without a reclosing circuit breaker would result in blown fuses and long interruptions of electric power to customers on the faulted feeder, even when a fault is temporary. When a reclosing breaker works to avoid long-term voltage interruptions, customers on the faulted feeder may experience up to three brief interruptions before power is automatically restored. But what are the effects of recloser operation on customers connected to parallel feeders on the same distribution bus?

Researchers at PEAC are studying the effects of a utility recloser operation on industrial customers connected to parallel feeders. During a fault, short-circuit current creates a voltage sag on parallel feeders, and successive recloser operations create voltage sags on the parallel feeders (see sidebar).

Utilities now have the opportunity to simulate the exact conditions of a recloser operation with PEAC's portable sag generator. "When a fault occurs," said PEAC project manager Doug Dorr, "we know exactly what happens to customers downstream from the problem—they lose power. But ultimately, everyone on the same bus is affected by some level of voltage sag during the fault. The porto-sag enables us to study the impact on *any* of the customers."

Voltage sags are one of the most common and costly power problems in the manufacturing industry. They can easily interrupt a manufacturing process, cause a loss of product, and damage equipment. In short, they can be just as costly as an outage. "The electric utility industry has taken steps to reduce the number of sags that occur in the electrical distribution system," said Dorr. "But we know sags are still going to occur. What we're trying to do now is to improve the tolerance of the customer's equipment to sags."

Essentially, the porto-sag allows researchers to identify those components most vulnerable to the types of sags resulting from power-system faults. "An entire process is only as sag-tolerant as its weakest elements," Dorr said. "In the past, if we wanted to study the effect of voltage sags on customers, we would have had to connect power monitors and wait weeks or months for the sags to occur. That, of course, is incredibly inefficient unless you can tell the future." Now, utilities can plug in and determine weak process elements in just a few hours, sparing their customers weeks or even months of inconvenient monitoring.

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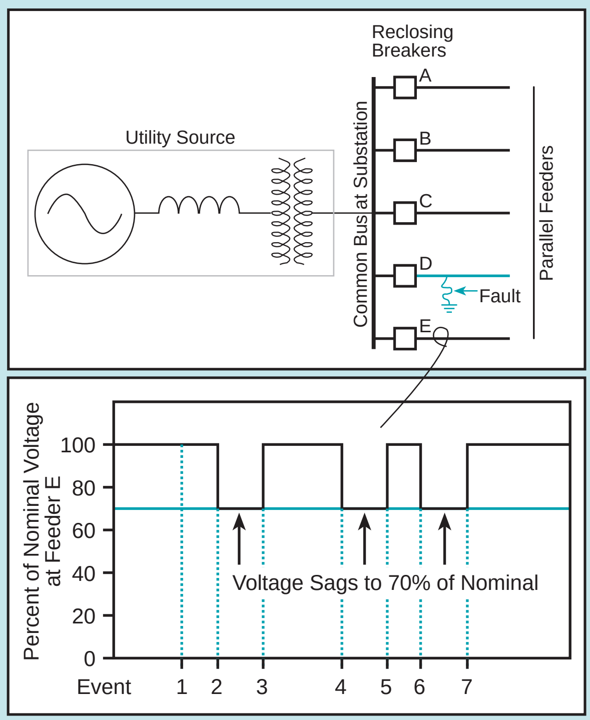
Anatomy of Recloser-Sequence Sags

Faults can be initiated by a number of events. Temporary fault conditions—that is, conditions that correct themselves—include small animals and windblown limbs crossing the power lines. Longer-term conditions include downed power lines and damaged hardware in the power system.

When a reclosing breaker opens during a powerline fault, it typically recloses and reopens up to three times if the fault does not self-clear. For example, during a fault, a reclosing breaker would detect the fault current and open the line, creating a power outage for everyone downstream of the fault. Then, the breaker would automatically reclose and perhaps open again if the fault has not self-cleared. If the fault has not self-cleared after several successive reclosures, then a line crew must manually clear the fault and reset the breaker.

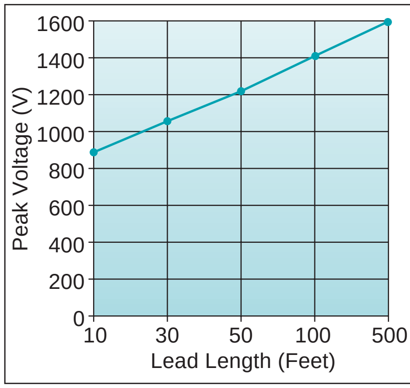


Event	*Description*
1	Normal Operation
2	Sag Caused by Powerline Fault (Feeder D)
3	Reclosing Breaker Opens
4	Reclosing Breaker Closes but Fault Remains
5	Reclosing Breaker Opens
6	Reclosing Breaker Closes but Fault Remains
7	Reclosing Breaker Opens and Locks Out

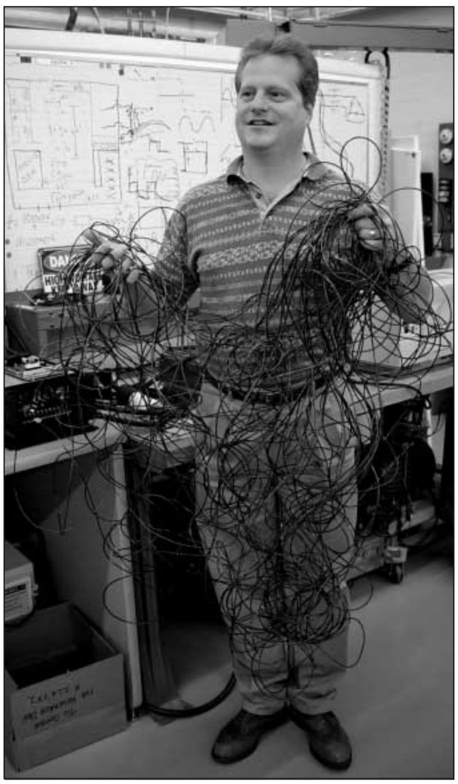
Research on long-lead effect will benefit process industry

According to Arshad Mansoor, the manager of PEAC's engineering team, early results of research at the Power Quality Test Facility have rendered the term "long-lead effect" a misnomer. "For years people have thought that overvoltages at motor terminals were the result of connecting PWM ASDs (pulse-width modulation adjustable-speed drives) with cables longer than fifty feet or so," Mansoor said. The long lead effect was assumed to be caused by the combination of long motor leads and the fast switching of PWM drives, which use IGBT switches with fast rise times for better control.

"Motors that have been around for decades were designed to operate with utility voltages," Mansoor said. "However, new PWM ASDs are routinely connected between motors and the utility system, which can result in higher voltages at the motor terminals." ASDs are essential for high-yield, high-precision processes. However, the higher voltage pulses produced by PWM ASDs can stress the motor's stator insulation system and significantly reduce the effective life of the motor. For example, the stator insulation system of most process motors is rated at 600 RMS volts. Yet an ASD-driven motor may bear peak voltages as high as 1600 volts.



Peak voltage at the motor terminals no doubt increases as the lead length increases. However, as this example shows, even a lead length of only ten feet results in a peak voltage of about 900 volts, still above the 600-RMS-volt rating of the winding insulation.


Power quality engineer Brian Fortenbery displays a tangled net of long motor leads, a cautionary metaphor for the process industry: Keep them short.

"Our testing has revealed that leads as short as ten feet still may result in terminal voltages as high as a thousand volts," said power quality engineer Brian Fortenbery. "The cutoff isn't 300 feet or 30 feet or even three feet—degradation of the stator insulation system is a matter of degree. The longer the leads, the more degradation, but the potential for degradation exists at all cable lengths." The size of the motor also plays a role in the degree of degradation. The smaller the horsepower rating of the motor, the more potential for insulation degradation.

"We're currently testing three different ASDs with three different switching frequencies and rise-time characteristics," Fortenbery said. "We're using cables from ten feet to 500 hundred feet connected to a five-horsepower, 480-volt motor and measuring the peak voltage at the motor terminals during normal motor operation. We are gathering all of this information with our next training sessions in mind. We'll not only be able to discuss all the problems we've found, but we'll also be able to provide solutions for each and every one."

Among some of the solutions that Mansoor and Fortenbery are considering to test are output filters, motors with high-voltage stator insulation systems, and 240-volt motors. "We're looking forward to the process industry embracing new motor designs that are compatible with PWM technology," Fortenbery said, "especially the new designs for inverter-fed motors promoted by the NEMA MG-1 Part 31 standard." Such motors have stator insulation systems rated for 1600-volt pulses.

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Sponsored by EPRI and its member utilities, the System Compatibility Research Project is a progressive research effort to improve compatibility between the power system and end-use equipment and appliances. By sponsoring a task of the project, utilities choose which equipment and appliances will be characterized. Utilities can finance their sponsorships through either a *Tailored Collaboration Agreement* or *Co-funding Agreement* with EPRI. All testing is conducted at PEAC's Power Quality Test Facility or at other test facilities within the Power Quality Testing Network.

For more information about sponsoring a research task, contact Gene Sitzlar, SC Research Project Coordinator, at 423-974-8288 or fax 423-974-8289.

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