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A POWER QUALITY NEWSLETTER

Voltage Sag Analysis—A Useful Power Quality Tool

by Larry Conrad, CINergy (formerly PSI Energy and Cincinnati Gas and Electric)

Voltage sags significantly affect industrial and commercial customers, causing more process interruptions than complete interruptions of electrical service. Yet, sags are not as obvious as interruptions. This leads customers to blame the utility and complain about declining service quality when, more likely than not, the problem stems from the process equipment.

Voltage sags deserve as much, if not more, attention than interruptions—the traditional focus of utility reliability assessments. For example, sags have caused load losses of 40 to 500 MW, and one event shut down over 2000 MW of utility generation.

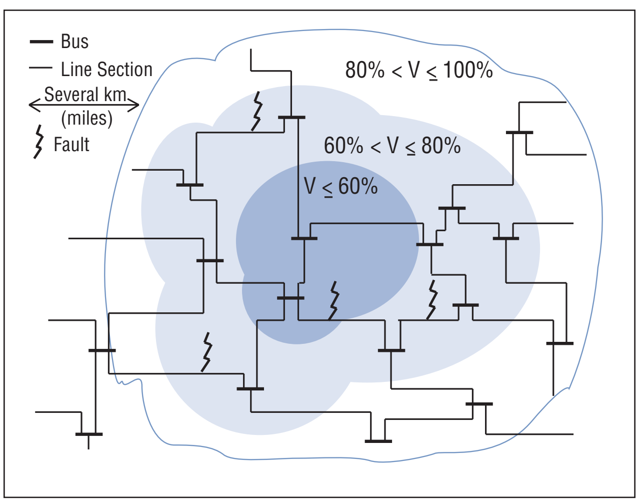
Voltage sag analysis enables facility designers to find the right balance between power quality, equipment immunity, and mitigation measures.

Customer-Driven Beginnings

Voltage sag analysis has evolved over several years of utility efforts to monitor and improve power quality, and help customers increase their immunity to electrical disturbances. For CINergy, it all began at a plastic-film extrusion plant in Indiana, which became concerned about declining reliability in 1984. Investigation revealed that voltage sags were causing most of the process interruptions. However, early discussions with the customer about sags and equipment immunity were frustrating at best. We launched several initiatives to improve power quality, but frustrations increased around 1986 when the customer started purchasing motor drives that were even more sensitive to sags. This new equipment virtually negated our first two years of effort to improve delivered power quality.

Efforts to improve equipment immunity were difficult, but one modification on the most sensitive equipment illustrated to plant engineers the liability of poor immunity to voltage sags. We convinced the motor-drive manufacturer to modify the sensitive drives. Modifications required two days of effort and virtu-

Tool: Continued on page 2



An electrical model of a local power distribution system simulates different fault locations and predicts the sag exposure of a sensitive load. Sag exposure predictions can be used to guide changes in utility power systems and end-user equipment immunity.

Point of View

Signature has a new look, but it is not just a facelift! The new eight-page format creates a forum for utilities to exchange real-world power quality challenges; power quality experts to offer insights into standards and their impact on customer business practices; and EPRI staff to share results of research and cooperative activities of the newly formed EPRI Power Quality Business Unit and the CUSTOM POWER Target of the Distribution Business Unit.

In 1996, we will seek the involvement of the IEEE Power Quality Standards Coordinating Committee (SCC-22) to expand standards coverage. We will also move toward a subscription basis for those NOT investing in the Power Quality Business Unit. Next year, only *Signature* subscribers will receive periodic *Special Reports* covering the most sought-after topics, such as wavelets and the "Emerald Contract" as developed by Electricité de France.

Signature complements the more extensive on-line information available to Power Quality Business Unit investors and augments Power Quality Interest Group meetings. We encourage funding utilities to join us on the Internet where you have exclusive access to our full range of information related to power quality, motors and drives, and end-use electronics.

Our design and content may be new, but *Signature* still offers the unparalleled expertise you have come to depend on.

See you on the Internet!

Marek Samotyj

Marek Samotyj, Team Leader
Power Quality and End-Use Electronics

Preventing Dropouts in Motor Starters

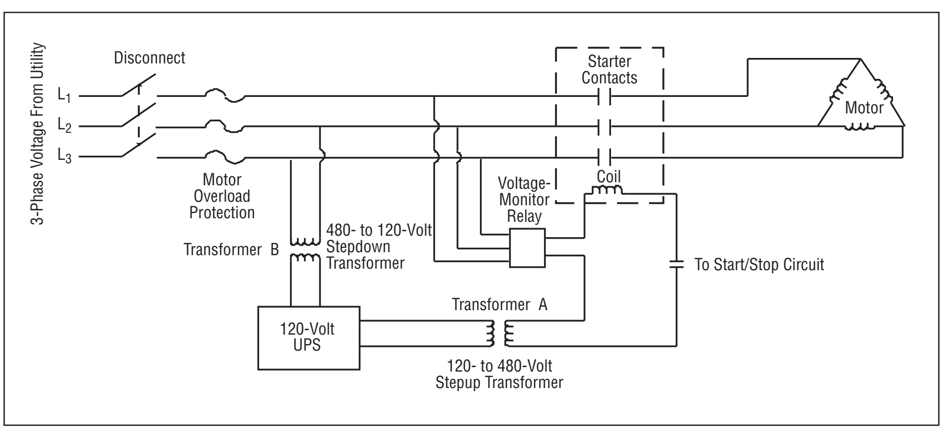
by Scott Peele, Carolina Power and Light

Lightning strikes a distribution line near an industrial complex. The resulting voltage sag causes the contactors of a process motor in one facility to drop out. The motor stops, even though overcurrent protection would not have been activated and the motor was in no danger of damage.

At another facility, process motors stop and will not start under load. The load must be manually removed before the motors can be restarted. At a third facility, the contactors of a remotely located motor with a manual starter drop out. The stalled motor clogs the production process, and facility personnel must visit the remote site to manually clear the clogging and restart the motor.

Contactor dropouts can significantly impact industrial operations. They disrupt processes and, as a result, increase the cost of production. To ensure a one-second ride-through for conventional motor starters in your facility, follow this procedure:

1. Obtain contactor coil data—inrush and sealed (hold-in) volt amperes —for all starters requiring protection. Determine the required volt-amperes (VA) by taking the square root of the sum of the squares of the inrush and sealed VAs. Add up to determine the VA load requirement for all starters to be protected.
2. If the contactor coil voltage is 120, go to Step 3. Otherwise, select a stepup transformer (if required for contactor coil voltages above 120), such as Transformer A in the diagram.
3. Select an uninterruptible power supply (UPS)—assume it is rated 120 volts in and 120 volts out—with a VA rating matching the VA load.
4. If the control power is 120 volts, go to Step 5. If it is above 120 volts, match a stepdown transformer to the UPS input requirements, such as Transformer B in the diagram.
5. Select a voltage-monitor relay with a time-delayed dropout, which breaks a circuit when the monitored voltage goes below preset limits for a preset duration. (The voltage-monitor relay can also be selected to protect a motor from single-phasing and overvoltage). Set the time delay for one second and the low-voltage setting for 90% of nominal. Check the motor overload protection to make sure an overcurrent on any phase will open the starter. ■



An uninterruptible power supply (UPS) together with transformers and control relays can be used to provide ride-through for ac motors during voltage sags and brief interruptions. This type of system sends continuous voltage to the starter coil without overriding motor protection.

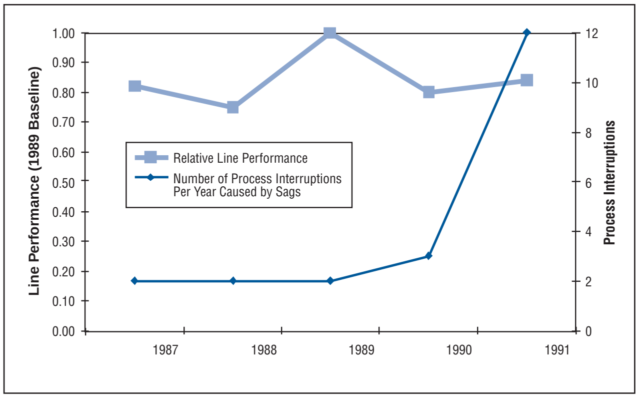
Tool: Continued from page 1

ally no equipment cost. About half of the drives had been modified when a sag hit the plastics plant at the end of the first day. Every modified drive survived. Every unmodified drive shut down. Although this in-plant effort proved the benefits of greater equipment immunity, the situation still needed some work on the utility side.

Our efforts to improve power quality produced favorable results. An early version of EPRI's MULTI-FLASH lightning analysis program identified opportunities to reduce interruptions and sags caused by lightning. Lowering line-pole grounding resistance made a real improvement, and modifying substations reduced problems caused by squirrel activity. Our handmade sag analysis calculations showed that changing the 34.5-kV subtransmission system to radial operation would significantly reduce sags for all customers. Reliability analysis revealed that radial operation would not degrade traditional reliability (number of interruptions per site per year). Fewer sags and increased equipment immunity made for a much happier customer. Since 1984, this plant's load has more than doubled and our customer claims to be the largest facility of its type in the world. Even better, an entire city now has better power quality as a result of our work for this customer.

The Evolution of Sag Analysis

Sag analysis combines fault analysis with data from reliability assessments. Fault analysis provides sag magnitudes for specific faults anywhere on the electric supply system. It often identifies hundreds of miles of line that, when faulted, could produce disruptive sags at customer sites. Reliability assessments estimate the number and duration of service interruptions at a customer site.



Customer process upsets have increased dramatically while utility distribution line performance has remained relatively unchanged.

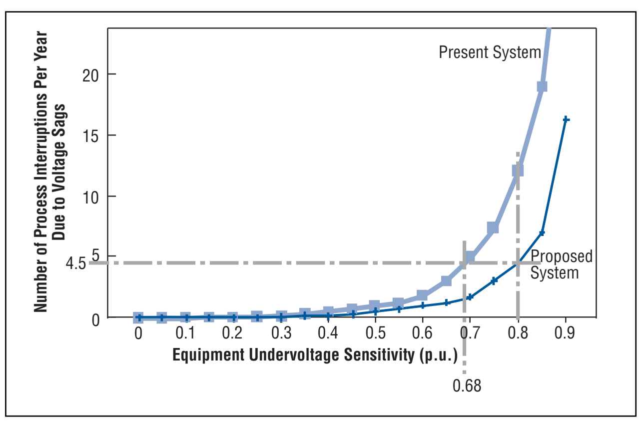
Combining these two power quality tools enables us to build systems on paper and estimate sag performance before construction of customer facilities. We can also estimate required equipment immunity levels before customers make equipment purchases.

These methods played a significant role with a major automotive manufacturer in Indiana. Around 1991, the manufacturer experienced a dramatic increase in production problems. A check of transmission-line performance showed steady power quality. Further investigation revealed recent increases in sensitivity to sags inside the plant. New process controllers would trip when line voltage dropped to 97 volts (on a 120-volt base) for 15 milliseconds. In a joint effort, CINergy offered several improvements to the external plant service while plant engineers investigated the immunity of internal equipment. They found that the air compressor controls tripped on overcurrent due to motor reacceleration after a sag. The customer changed the protection setting, but left an alarm which confirmed after the next sag that the changes had made a difference. In this case, we found simultaneous efforts to improve power quality and equipment immunity achieved better results than either effort alone.

Modern Sag Analysis

Early sag analysis required considerable engineering effort, with a final report easily involving several thousand individual fault calculations. Crude automation of the calculations helped, but the work for one customer typically took several weeks.

Two developments have made sag analysis more practical, reducing the process from several weeks to a few hours. First, some of the new fault analysis packages support macro-languages. These languages automatically divide lines into sections, apply faults, estimate sag magnitudes, record results, and decide what to do next. Second, these packages provide access to impedance data, which is a good indicator of overhead line length. Failure rates per unit length become failure rates per unit of line reactance. The macro-language can accept failure rates by unit of reactance and produce a data table for graphic presentation.



In this voltage sag analysis, dashed lines compare the performance of a present supply system with an improved system. Relating these lines to equipment sensitivity at 0.80 per unit, the right vertical line shows sag problems dropping from about 12 to 4.5 per year through system improvements. The horizontal line illustrates that changing equipment immunity from 0.80 to 0.68 could achieve the same results.

Sag analysis techniques continue to develop. One area of study is time-varying sags from motor reacceleration. Another is how to report sag voltages on individual phases: should we report the lowest phase, the average of the three, or each phase individually? Another area is how to report multiple sags from reclosing operations. If sags occur very close together, the customer may count many sags as only one event. And, what is the best way to graphically show the results? Work is under way with the Institute of Electrical and Electronics Engineers (IEEE) and EPRI's Distribution Power Quality Project to address these issues.

Acceptance of sag analysis is growing. An IEEE working group is writing a new chapter in IEEE Standard 493, the *Gold Book*. Sag analysis is also showing up as an option in several computer programs.

Voltage sag analysis allows designers to compare performance of supply-side solutions to in-plant immunity improvements. It is possible to estimate the costs of both alternatives and to include downtime losses to find the best solution. Sag analysis promotes better understanding between the electric supplier and customer, and allows mitigation equipment designers to estimate the value of custom power options. Even though there are still unanswered questions, voltage sag analysis is useful today and will only be better tomorrow. ■

User Equipment Improves Factory Ride-Through Performance

by Larry Morgan, Duke Power Company

Times were simpler when utilities first got into the business of electrification. Electricity, then a luxury, powered passive loads that illuminated our homes and motorized our factories. As new uses for electricity evolved, so did the sophistication of the appliances. Radios, televisions, and rectifiers ushered in the electronic age in the 1960s and '70s.

Today, the proliferation of electronic devices and equipment that provide automation, sensing, and motor control in process industries is reshaping how we use electricity and has created a demand for cycle-to-cycle continuity of power. We are beginning to see a gap between what the power system was designed to deliver and what today's more demanding loads and processes are designed to take.

The power quality requirements of more sophisticated and sometimes sensitive process equipment typically go beyond what is available in a factory electrical environment. Utilities are seeing this mismatch firsthand as their customers call for help when critical processes are interrupted. Utility service contracts specify a service-entrance voltage that varies no more and no less than 10% from the nominal voltage. But disturbances beyond this range—often caused by customer equipment—are inevitable.

Efforts to address incompatibilities from the utility side of the meter are often cost-prohibitive. Manufacturers of equipment used in factory processes usually design the equipment for normal conditions and treat electrical disturbances as special cases. What end-users don't know about their equipment performance can hurt them when they pay the price of process interruptions and destroyed materials. To close the gap between available power and factory equipment power requirements, some preventive measures are needed. The payback will be in customer productivity and perceived value of electricity.

Working in a textile plant, Larry Morgan of Duke Power (right) uses a portable sag generator to investigate power quality problems in a knitting machine.

The Search for Solutions

The costs of factory process interruptions have prompted a number of preventive methods and equipment. More information is now available to predict voltage sags and interruptions in utility service. New devices designed to solve industrial power quality problems are appearing on the market, but the costs are typically too high for blanket application.

So, what is the best way to identify solutions to process system compatibility problems? The following case histories illustrate some of the answers to this complex question.

- In one textile factory, many of the 1600 identical sock-knitting machines with motors controlled by adjustable speed drives (ASDs) and programmable logic controllers (PLCs) were upset when wind and lightning sagged the voltage. Process interruptions resulted in hundreds of pairs of partially knitted socks being trashed, needles damaged, and man-hours lost. ASD and PLC samples were tested and were found to have a sufficient ability to ride through voltage sags. It was only by using a portable sag generator on-site and testing the knitting machines as a system that a weak link was found in one of 12 small power supplies inside the knitting machine. The problem was solved by replacing this power supplies for less than $30, and factory process interruptions decreased from 87 in one month to 3.
- In North Carolina, a medical products company purchased robotics-controlled welding machines that were specified to have three-second ride-through during low voltage. However, during the storm season 50 of these welders were interrupted almost daily, leading to a desperate call for utility help. Investigators found that a photo-eye controlling an emergency stop was powered by a simple doorbell transformer which provided no ride-through capability. Powering the photo-eye from a stronger source reduced weld process interruptions significantly.
- During the same season, an extrusion plant near Charlotte suffered 18 machine shutdowns per week, requiring six hours per machine to restart the process and costing the plant a substantial loss of production. Investigation revealed that the large-horsepower dc drives were sensitive to voltage sags. Prototype control boards—recently developed to improve drive ride-through—were applied to 10 of the large dc drives. Tests indicate that the enhanced dc drives will ride through most common voltage disturbances experienced at this plant. This is expected to be proven out during the next storm season.

- A nonwoven textile factory that produces diapers experienced many shutdowns during periods of wind or lightning. The company also operated a toilet paper manufacturing facility and was using many effective ride-through devices in its production process. Applying this experience to the diaper plant, the company installed ride-through devices inside the drives on the dc link and uninterruptible power supplies on the external coils, logic circuits, and contactors. However, the factory still experienced production interruptions. Investigators found that measures were working and that the plant was riding through voltage sags. However, they also found that a mechanical ripple in the fabric web —caused by the recovering equipment—would trip the process and interrupt production. Ironically, it was the excellent dynamic responsiveness of the process ASDs that led to the problem. So far, there is no solution to this case, but a laboratory mockup of the process is expected to shed new light.
- A plastic-recycling factory purchased state-of-the-art process equipment containing multiple small motors controlled by one ASD. During voltage sags, several of the motors (never the same ones) would drop off-line while others continued to operate. This led to out-of-tolerance variance in the diameter of extruded plastic. An equipment characterization showed that the contactors between the ASD and the motors had sufficient ride-through except when a sag occurred at a critical point on the voltage sine wave. Based on this information, the factory replaced the ac contactor coils with dc coils, making the problem worse. Further investigation of the dc contactor hold-in circuit revealed an overloaded power supply for the new coils during a sag, collapsing the dc voltage and resulting in random contactor dropouts. This problem was easily fixed, once discovered, by increasing the size of the control power transformer and upgrading the rectifier supply to the dc contactors.

Hotline Highlights

Problem: During voltage sags, the process controllers of a plastics factory in California tripped process motors. Hundreds of employees would wait nearly three hours while the process was brought back online, and incompletely processed materials had to be discarded.

Utility engineers connected a power line monitor to profile the type of disturbance interrupting the motors. Recorded data revealed that any voltage sag below 80% of nominal voltage and lasting at least four cycles—or to zero volts with a duration greater than one cycle—could interrupt the process.

Further investigation showed that the disturbing sags were caused by events both inside and outside the factory. For example, heating loads sharing the same feeder as the process equipment were causing some of the sags during startup. Also, weather-related faults in the power system caused sags.

Solution: Factory engineers decided to implement a two-pronged solution. First, they electrically relocated the critical process equipment to a dedicated feeder—away from the sag-causing loads. Second, they supported the process controllers (a small percentage of the total process load) with voltage-regulating uninterruptible power supplies.

Highlights come from the PEAC Hotline. If you have problems you would like addressed, call 1-800-832-PEAC.

The Need for Systematic Tests

These real-life cases illustrate the system details and process idiosyncrasies of solving ride-through problems. Correcting a weak link at one level often exposed a problem at another level. Nevertheless, in every case characterizing the factory process equipment both individually and as a system—including simple non-electronic relays and controls—was key to solving the ride-through problems.

The process industry and power providers need a systematic way of defining compatibility levels for the myriad electronic equipment and components of industry. This may require characterizing the entire process system in its normal environment.

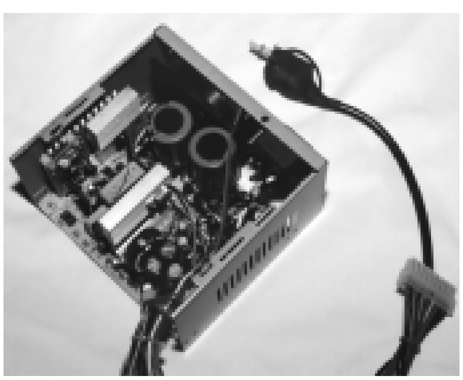
Case histories may help others to troubleshoot in the field, but they do little to bridge the compatibility gap between manufacturers and power providers. Without systematic characterization, compatibility parameters will remain a mystery or, at best, continue to be discovered by trial-and-error during expensive on-site investigations. Manufacturers, end-users, and utilities must come together to bridge the compatibility gap. Recent efforts in characterizing user equipment are laying the foundation and may indeed restore the compatibility that utility customers enjoyed in simpler times. ■

For related information, see *SC News: Using PLCs to Control Automated Production*, page 7.

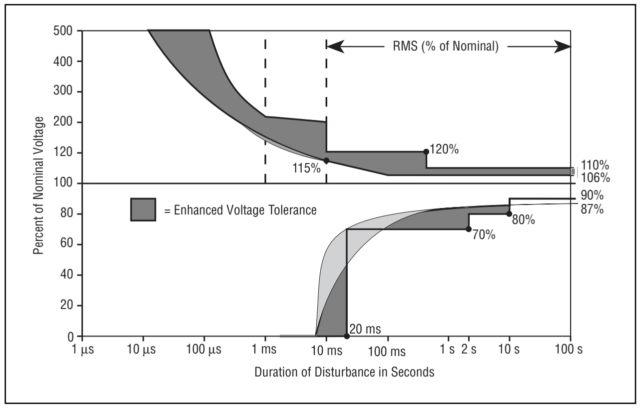
PEAC Proposes New Curve to Computer Manufacturers

According to many in the power quality field, the shape of the Computer Business Equipment Manufacturers Association (CBEMA) curve needs updating. The CBEMA curve recommends maximum and minimum voltage-tolerance limits for office equipment and defines the basic voltage envelope in which most office equipment can operate without problems. Tom Key at EPRI's Power Electronics Applications Center (PEAC), believes that while modern power supplies meet the limits of the CBEMA curve, they sometimes fail in the typical electrical environment.

Key presented a proposal to update the CBEMA curve at the Information Technology Industry Council meeting in February 1995 and is heading efforts to draw a new curve that reflects today's changing power supply technologies. Key believes that modernizing the curve will make it more significant to today's business equipment industry. He bases his assessment on the results of Task 2 of the EPRI System Compatibility Research Project, which characterized modern power supplies from personal computers (PCs). These results are enabling PEAC to catalyze a movement toward using a new curve to design more system-compatible office equipment.



PEAC tests PC power supplies to confirm that off-the-shelf capacitor technology can enable power supplies to ride through voltage sags and interruptions lasting as long as one-half second.



The updated CBEMA curve would expand the voltage-tolerance envelope of business equipment.

"We've learned a lot in this PC task, and we want to share that information with manufacturers," says Key. "We discovered and demonstrated that some performance problems could be easily corrected with small design changes." For example, simply increasing the storage size of the energy-storage capacitors in modern power supplies can significantly extend their ability to ride through voltage sags.

Industry insiders recognize that the current CBEMA limits are less than the already-achieved performance levels of PC power supplies. Based on this knowledge and PEAC's test results, Key wants to update the voltage-tolerance envelope so manufacturers will continue to build office equipment that can tolerate higher voltages and ride through longer voltage sags.

Related information from the PC task will also enable business equipment manufacturers to consider such pivotal issues as the intended real-world electrical environment, growing consumer demand for reliable computers, and an increasing industry need to serve global markets with power quality that varies by location.

"In the 17 years since the CBEMA curve was designed, we have developed better tests and a greater understanding of the electrical environment," says Key. "We need a curve that matches PC equipment with the electrical environment."

Key should know. He was instrumental in creating the original curve in 1978 and is a logical candidate to lead the modernization of the curve. "The original curve was a struggle to put together," recalls Key. "It was a committee agreement on what people thought the equipment could stand. It was not thoroughly tested or verified at that time."

Although the technologies of business equipment have improved, manufacturers are still reluctant to incorporate them into their power supplies because of competitive market constraints. Key believes that a new CBEMA curve could challenge manufacturers to apply today's technology, since the curve is used as a default design standard. "In a manner of speaking, it has become an industry standard because it is used as a means to judge equipment power supplies and the electric power system," he says.

For Key, the ultimate goal is simple: to help manufacturers design and build better products for consumers. Yet, he and many others are concerned about a relaxation in design goals that does not take advantage of modern technologies. "If manufacturers simply settled on meeting the present CBEMA curve, PCs would be at a lower performance level than we saw in the 1980s," he says. "This is clearly the wrong direction. We use and depend more upon these electronic marvels every day and can't afford incompatibilities." ■

Using PLCs to Control Automated Production

Considered by the industrial community as its automation backbone, the programmable logic controller (PLC) is now under the close scrutiny of engineers at EPRI's Power Electronics Applications Center (PEAC). In a project to characterize the response of PLCs to voltage sags, engineers are installing PLCs in a simulated system that controls the production of textiles and paper.

"The PLC has the ability to perform repetitive operations with a high degree of precision," says Project Engineer Mark Stephens. Introduced to the manufacturing industry in 1969, the PLC is designed to withstand the effects of electrical noise, high humidity, and mechanical vibration—all inevitable consequences of factory production.

This hardened industry performer has also been embraced by the electric utility industry. Utilities are beginning to use PLCs in substation applications and to control power distribution systems, such as the switching on of power-factor-correction circuits. As PLC users, utilities will benefit from the PEAC test results by gaining a better understanding for applications and improving the system compatibility of customer equipment.

Testing the PLCs for immunity to voltage sags consists of isolating them from the process they are intended to control and then installing them in mock process systems to determine how the entire system reacts to voltage sags.

"We're simulating a textile mill to understand the issues related to a typical control system in that setting," says Stephens. "The PLC is part of an ensemble of equipment —usually a PLC, adjustable speed drive, relays, and an array of sensors —used to maintain continuous operation of critical processes. The trick is to figure out which control device is the weak link in the system."

PEAC's Mark Stephens (left) and Doni Nastasi talk about fine-tuning the PLC project's test setup. The PLC (shown mounted at the top of the control board) is the brains of this simulated textile/paper production process.

Faltering process controllers have threatened industrial productivity since the introduction of automated production and continuous processing. Freely spinning lathes, spools, and stretchers can ruin materials. Following an upset, cleanup and restarting can add tremendous costs to the production of textiles and other goods.

"When a control system shuts down during a voltage sag, paper tears, threads break, and extruders may go out of control, making a metallic mess," says Stephens. "A single sag can result in a lot of downtime and wasted material."

Like its cousin the personal computer (PC), the PLC makes decisions based upon data it gathers from outside its central processing unit. Inputs to the PLC indicate the status of various field devices, which show how fast a motor shaft is turning and how tense a material is. The PLC uses these and other inputs in a program that controls the entire production process.

Although the project will subject PLCs to many different types of electrical disturbances, the textile mill test setup will be used primarily to characterize the response of a process system to voltage sags.

"Voltage sags are by far the most upsetting type of electrical disturbance for control systems," says Stephens. "Based on the results of EPRI's PC system compatibility project, I don't anticipate overvoltages or capacitor-switching transients to be much of a problem for PLCs," says Stephens.

Sponsoring utilities are glad to see sag testing conducted on the process systems, and manufacturers are enthusiastic. Installation of the mock process systems should be completed by the end of 1995. ■

EPRI R&D Corner

- *Revolutionary Power Quality Problem Recognition Device*—Stop worrying about power interruption complaints. EPRI's new PQPager monitors power quality right at the meter, phoning you with a synthesized voice analysis of a problem when it happens. PQPager allows you to take quick steps and proactively solve power quality problems. All for only $1,000! For more information, call Sid Bhatt at (415) 855-8751.
- *Important Health Care Power Quality Project*—Hospitals across the country are especially concerned about harmonic and voltage disturbances that affect the operation of CT scanners, MRI equipment, and other medical electronic devices. The EPRI Health Care Power Quality Project enables you to work with major health care facilities in your service area to assess problems and implement solutions. To participate, call Sid Bhatt at (415) 855-8751.

Power Quality Standards Update

by Tom Key, EPRI Power Electronics Applications Center

The electronics revolution has opened a whole new chapter in standards development activities by dramatically changing the nature and requirements for powering electrical equipment. The Institute of Electrical and Electronics Engineers (IEEE) currently has at least four societies and dozens of committees, subcommittees, and working groups pondering power quality definitions, guidelines, practices, and limits. In 1991, the IEEE Standards Board established Standards Coordinating Committee (SCC-22) to support and coordinate the many new power quality standards projects and to keep track of international power quality standards activities. This committee will provide *Signature* a window into the world of power quality standards.

International standards are of growing importance to U.S. companies. Standards will play a pivotal role in the success of global business relationships, and power quality already has a position in this marketplace. The International Electrotechnical Commission (IEC) has become the primary world body for setting electrical norms. Within IEC under the topic of electromagnetic compatibility, a committee and several subcommittees oversee power quality-related standards.

Despite differences in language, the technical categories used in international power quality standards are similar around the world. For simplicity, consider three pieces of the standards pie related to harmonics, undervoltages, and overvoltages.

There are two very different ways to control harmonics: one at the point of service, the other at the plug. The IEC has passed limits on harmonic currents at the appliance level. IEEE, on the other hand, has approved a standard for maintaining nearly sinusoidal voltages at the point of common coupling between customers and the power system. Not too surprisingly, each organization is looking carefully at the other's point of view.

For undervoltage conditions, terminology has been a challenge. IEEE uses the terms *sag* or *momentary interruption*, while the IEC calls the same condition a *voltage dip* or *short-time interruption*. But, neither organization has been very aggressive in recommending specific ride-through requirements to improve equipment immunity. Undervoltages are common and widespread during power system faults, and the power quality community regards them as a major source of incompatibility. Increasing pressures toward standardization are expected for this area.

In the surge world, a great deal of standardization is already in place. Due to the efforts of a few volunteer standards bearers—namely François Martzloff of the U.S. National Institute of Standards and Technology—the approach is fairly consistent between the IEC and IEEE. But again, terminology is a hot issue. Some are digging in to defend the term *surges* against *oscillatory* and *impulsive transients*, and to uphold *temporary overvoltage* as colloquial against the upstart *swell* alternative. ■

This column will be an open forum on power quality standards activities and new standards developments. Let us know your preferences between the IEEE and IEC approaches. Share your experiences applying these standards and your questions about interpreting them. Send your comments to Tom Key at tkey@msm.epri.com

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