EPRI

SIGNATURE™

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Point of View

Should quality of power be a revenue-generating enterprise? That's a tricky question, as electric utilities around the world contemplate charging higher rates for a premium product. Many utilities regard deregulation as a panacea that will improve their operations, reduce costs, lower customer bills, and enhance the quality of power. This vision contains both myth and reality—and still no answer.

At a recent EPRI workshop cosponsored by the Power Quality Target and Power Electronics Applications Center along with Texas Utilities Electric, a presenter from a leading U.S. semiconductor manufacturer shared information associated with less-than-perfect power quality at their company. The numbers were staggering: On average, the cost of an event causing a one-day interruption of production was $850,000. With product losses, this cost skyrocketed to more than $1.5 million! Complicating the situation is the move by semiconductor manufacturers toward fully automated factories and tools, which heightens a plant's sensitivity to voltage sags. In more automated plants, a 10% voltage drop sustained for 10 cycles will knock out all microprocessor-based operations.

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Power Quality Contracts Benefit EDF Customers

by Pascal Fauquembergue and Eric Mathieu, Electricité De France

The availability of sophisticated and sensitive new technologies has led customers to demand higher levels of power quality. To meet these needs, the French national utility—Electricité De France (EDF)—has instituted a range of power quality contracts and services for large and medium-sized customers.

In 1994, EDF initiated the *EMERAUDE* ("Emerald") Power Quality Contract as a two-year experiment with 6000 test cases. The contract was developed in a cooperative effort between the utility and customer representatives. In 1996, EDF extended the contract for another two years to 140,000 high- and medium-voltage customers, mainly industrial and commercial users whose contractual demand exceeds 250 kVA each.

A Commitment to Power Quality

EMERAUDE applies the principle of compensating customers for damages incurred should the utility exceed an agreed-upon limit on the number of power disturbances. In the contract, EDF guarantees

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Detroit Edison Launches Service Guarantees in U.S.

by Mark Brown, Detroit Edison

The Detroit Edison service area in southeastern Michigan is home to the "Big Three" U.S. automakers— Ford Motor Company, General Motors Corporation, and Chrysler Corporation. With 55 plants consuming more than 5000 GWh annually and a combined demand of 1000 MW, these companies are the utility's largest customers.

In 1993, realizing that the quality of power would play a significant role in securing agreements with these important customers, Detroit Edison developed its Special Manufacturing Contracts (SMCs). Negotiations with the auto companies resulted in three 10-year contracts, which were signed in August 1994 and approved by the Michigan Public Service Commission in March 1995. They are the first agreements of their kind in the U.S. electric utility industry.

The purpose of the SMCs is to assure long-term electric revenue for Detroit Edison and to establish the utility as a preferred, value-added supplier to the auto industry. In exchange, the auto companies have agreed to buy their full electrical requirements in southeast

Photo courtesy of J. Crachiola/Detroit Edison Company

Power disruptions to automotive processes, like this component assembly at Ford Motor Company, can result in production downtime and revenue losses. Detroit Edison has developed a unique set of guarantees for automakers that define limits on sustained and momentary interruptions.

Detroit Edison: Continued on page 10

A Complete Approach to Power Quality at Eskom

by Tim Hennessy, Eskom, South Africa

Eskom, the world's fifth largest utility, has implemented a uniquely comprehensive quality-of-supply program over the last five years. The utility places such high priority on this program that it links the performance of its electrical networks to remuneration for senior management. Program development has been driven by the expressed needs of customers for enhanced power quality levels, and by the changing face of South African industry since its reacceptance in world markets following the demise of apartheid.

Eskom commenced efforts in 1992 by initiating extensive, ongoing power quality measurements at more than 150 of its transmission and distribution substations to quantify the levels of power quality experienced by customers. This sample represented 30% of the power system and covered 80% of Eskom's revenue-generating base ($5 billion in 1997). The primary reason for the measurement program was to address an increase in customer plant sensitivity and, hence, greater awareness of power quality. In addition, a major new electrification program, in which some 300,000 to 500,000 new customers were being connected to Eskom annually, was raising concerns about the potential for degradation in power quality levels.

Determining Costs and Solutions

In conjunction with the power quality measurements, Eskom embarked upon two other initiatives. First was a power quality performance survey—a series of personal interviews with over half the utility's large customers (>5 MVA)—to determine the actual costs incurred by customers due to power quality variations. A figure of $350 million per year emerged from the survey. Results were used to develop a normative economic model for six sectors of industry— chemicals, pulp and paper, gold and coal mining, textile, food and beverage, and metals. Use of this model allows Eskom to predict customer costs for each type of power disturbance and has been incorporated into the utility's power system planning.

Eskom also began investigating high-power solutions to power disturbances for application behind the meter. The utility identified a number of new technologies, then purchased and installed at customer sites three "new" devices from competing technologies—the Statordyne, Written-Pole™ motor-generator set, and Superconducting Storage Device. (The number of installed technologies has since increased considerably.)

Objectives of this initiative were to
1.) demonstrate concepts for behind-the-meter solutions, and
2.) develop competence and tools to allow the integration of new technologies within the power system.

The problems associated with combining such large devices with complex loads and networks have been amply reinforced by the experiences of other utilities, most recently in the United States. (See *PQ Pointer* on page 11 for lessons learned.) In these instances, several new technologies have been applied to conventional utility network situations, such as VAR compensation, as well as to high-tech customers requiring continuous power.

Contracting for Power Quality

All three of the above efforts were key to the development of Eskom's premium-quality power services package—a product introduced in August 1996 under the brand name *Sine~On*™. This product guarantees customers enhanced levels of power quality, on a contractual basis, for an agreed term and at a fixed monthly charge. Profit is made on the service element of the contract and is not linked to energy usage. If performance levels are not achieved, Eskom reimburses the customer to the amount stipulated in the contract. The customer is free to withdraw from the contract after an agreed period of notice and can also increase the size of a protected plant through negotiation.

Sine~On works in this way:
1. A customer requests a level of power quality above what the system can deliver.
2. Eskom performs a technical study of the customer's plant and electrical networks to determine the sensitivity of plant equipment and how often power disturbances occur.
3. Eskom develops and designs a set of solutions to meet the required power quality performance levels.

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Photo courtesy of Eskom

As part of a premium-quality power contract, Eskom installed a Superconducting Storage Device, shown above, to dip-proof a 1-MW variable speed drive paper machine in the province of Kwa-Zulu Natal.

Con Edison in Premium-Power Partnership of the Future

by Pete Hofmann, Consolidated Edison

The New York Information Technology Center (IT Center) at 55 Broad Street is downtown Manhattan's state-of-the-art office tower. Along with a fiber-optic communications infrastructure, advanced lighting, and dedicated air conditioning upgrades, the building incorporates clean-power motor-generators to provide its high-tech tenants with premium power quality.

Consolidated Edison—in a unique partnership with the New York City government, the Alliance for Downtown New York, and a host of entrepreneurs, educators, and industry leaders—has turned 55 Broad Street into a hub for the information superhighway. Developed at a cost of $15 million over the last two years by Rudin Management Company, Inc., the center targets the special needs of information technology businesses. Such businesses include Internet, multimedia, communications, and software development firms.

Already about 90% leased, the IT Center has attracted more than 60 tenants, ranging from record producer Phil Ramone to Cornell University's supercomputer operation. Other tenants include

- IBM Corporation, an original proponent of the center, which houses the content and technical team for its Internet home page and internal communications network;
- N2K, which operates a music-entertainment site on the Internet;
- CertCo, a developer of software and legal contracts that enable banks to offer electronic products; and
- Studio Archetype, a San Francisco-based company that develops and designs web pages.

The IT Center occupies more than 400,000 square feet in the 31-story office tower. It provides tenants with hookups wired into the building infrastructure for high-speed voice, video, and data transmission; a local area network; advanced telecommunications and data security; satellite communications for videoconferencing and transmission of other visual material; and high-speed Internet access.

The center also offers Con Edison's premium-power system, which incorporates redundant, on-site motor-generators to serve and protect sensitive electronic end-user loads. The cost of premium power is built into the rent, which ranges roughly between $15 and $30 a square foot per year in a special introductory lease offering. There is also a one-time charge for being wired into the system.

The project has been so successful that other landlords have begun to copy it. Earlier this year, the owners of six other downtown Manhattan office buildings announced they would wire their buildings for high-tech tenants. Con Edison has and will be working with these customers, although not to the same extent as the IT Center, which is a showcase for this kind of service.

Photo courtesy of Con Edison

Con Edison's premium-power service minimizes power quality concerns for tenants of the New York Information Technology Center.

Protecting Sensitive Loads

Today's sensitive computer and multimedia equipment require clean electric power that is protected against normal split-second voltage variations. To provide this premium power at the IT Center, Con Edison's Research and Development and Power Quality groups studied, selected, and installed state-of-the-art, EPRI-sponsored Written-Pole™ motor-generators and related switchgear. It is the first installation of its type in New York City.

Operating in tandem with the Con Edison network system and using advanced control technology, the three-phase motor-generators assure protection against power disturbances in virtually all situations. Three Written-Pole motor-generators, each rated 35 kVA, operate in parallel to provide essential electrical loads with a continuous source of clean, regulated, and isolated 60-Hz power. Switchgear includes automatic and manual bypass of the motor-generators initiated by programmable logic controllers. Monitors record details of any power disturbances on both sides of the motor-generators.

This unique electrical service configuration furnishes between 15

***Con Ed**: Continued on back page*

CEPEL Establishes Advanced Power Quality Laboratory

by Antônio Guilherme Garcia Lima and Ricardo Penido Dutt Ross, CEPEL, Brazil

CEPEL, a center for electrical research in Rio de Janeiro, Brazil, is sponsored by the national electrical holding company, ELETROBRÁS, and 24 Brazilian utilities. Over the last two decades, CEPEL has developed a wide range of laboratory facilities and prod-ucts for addressing power quality concerns.

In November 1996, CEPEL added the Power Quality Advanced Laboratory (LABQ) to its laboratory network. Equipment and software installations at the laboratory are targeted for completion this year. Although not entirely installed, LABQ is able to provide analysis, diagnosis, simulation, and measurement of power quality problems, while developing new tools and equipment to improve power quality diagnosis and performance.

LABQ has been created specifically to support the power quality investigations of Brazilian and South American utilities and their large industrial customers, which are rapidly growing in the wake of utility deregulation and expanding economies. LABQ's products and services are designed to provide newly privatized utilities with a competitive edge in the new market. These products and services also benefit Brazil's large industrial customers, which face greater competition due to a new federal policy of open import and export markets.

A Case in Point

In 1994, a steel mill in Rio de Janeiro was experiencing disruptions to its rolling mill and production process due to voltage sags. These disruptions had been occurring at the steel mill since its construction, 20 years earlier. The utility serving the steel mill also had concerns about harmonics and flicker in its system. CEPEL managed the power quality investigation, which followed three steps:

1. *Preliminary Simulations*. Software programs were used to predict the number of voltage sags experienced by the steel mill in a one-year period. Harmonic and flicker levels were also projected for the utility system.
2. *Measurements*. The steel mill was monitored in several locations for one year to gather data on its voltage and current profiles.
3. *Data Analysis*. The resulting database was analyzed to correlate several variables, including active and reactive power, magnitude and duration of voltage sags and transients, and total harmonic distortion of voltage and current.

Results showed that voltage sags due to faults in the utility system were numerous and that many of these sags were causing disruptions to the rolling mill. CEPEL recommended internal and external solutions: to adjust the undervoltage protection of the steel mill's dc drives, and to maintain in a spinning reserve status a nearby electric power plant owned by a neighboring utility company. Together, these solutions reduced the number of outages from three to less than one per month, representing an annual savings in production downtime of more than $1 million.

Photo courtesy of CEPEL

In the future, the Transient Network Analyzer Laboratory (above) will be integrated with LABQ. This will allow system studies to be better integrated with individual customer power quality needs.

CEPEL also found that a high number of rolling mill outages, which had been incorrectly attributed to voltage sags, were due to problems within the customer's process and were not related to the utility system. Regarding the utility's concerns, the investigation determined that harmonic levels were acceptable, while voltage fluctuation levels causing light flicker needed to be reduced. The investigation prompted CEPEL to recognize the growing need for and importance of power quality investigations and centralized expertise, as offered by LABQ.

A Family of Services and Products

LABQ is the latest addition to the CEPEL laboratory network. Another quality-related facility is the Transient Network Analyzer Laboratory, which was formed in 1979. It calculates overvoltages resulting from utility system operations, such as transmission line switching and reclosure, transformer energization, load rejection, and capacitor switching.

The Electromagnetic Compatibility Laboratory, established in 1985, tests customer electronic equipment known to create high levels of electromagnetic interference. It contributes to power quality investigations by pinpointing problems due to interference from customer equipment rather than the electric power system.

The Adjustable Speed Drive and Motors Laboratory, in operation since 1994, tests adjustable speed drives (ASDs) and electric motors to

CEPEL: Continued on page 11

PQ Database Gets a Workout

by Steven G. Whisenant, Duke Power Company

In its first year at Duke Power, the EPRI Power Quality (PQ) Database™ has shown remarkable flexibility and stamina. Already, we have added more than 500 case studies to the 50 included in the original release. We have exercised the database's report-writing capabilities to generate management-level summary reports, and have used the database to measure various aspects of our power quality process. In addition, through a tailored collaboration project with EPRI, we have customized several features within the database to gather valuable information about customer problems, their causes, and solutions.

Keyword Power

Keywords, which serve to capture the most common problem occurrences and establish trends, are a critical component of the PQ Database at Duke Power. For example, a SEARCH on the *keyword* "Affected Equipment" shows that drives are involved in nearly 25% of our industrial customer inquiries. By further dissecting into this *keyword*, we learn that ac drive problems outnumber dc drive problems six to one.

We use this type of information to steer our research and development activities. With the knowledge that ac drive problems represent the vast majority of drive problems, we have sharpened our focus on understanding their causes and on developing solutions. This information can also be utilized collectively within the electrical industry to enhance the design and compatibility of end-use equipment.

The *keyword* "PQ Event Category" is used to collect customer descriptions of equipment responses to electrical disturbances. It shows, for instance, that the top three equipment responses for our industrial customers are equipment/component failure, nuisance tripping, and drop-out. A further SEARCH on the *keyword* "Customer Types" displays customers by industry type and tracks common power quality problems among similar industrial processes. We apply this information to the development of customer case studies and resource materials, such as the EPRI brochure, *Power Quality Considerations for the Textile Industry* (BR-105425).

A SEARCH on the *keywords* "Problem Causes" and "Solutions" gives us insight into the most common causes of power quality disturbances and the most frequently applied solutions. We use this intelligence to determine subject matter for customer workshops and seminars. Statistics generated by these *keywords* also allow us to recommend the most commonly applied solutions to particular problems.

The EPRI PQ Database stores and retrieves information related to power quality investigations.

Tracking Strength

The PQ Database is instrumental in our internal tracking and measurement efforts, which are critical to the success of the power quality process at Duke Power. Our field power quality specialists, for instance, use the database to log time spent on travel, investigation, data collection and analysis, and customer consultation. These records allow us to evaluate the number and location of specialists in the field versus the volume and geographic distribution of inquiries. They also help us track the type and usage of power monitors to determine if our field teams have adequate equipment.

About the PQ Database

The EPRI PQ Database™ is designed to help evaluate power quality problems on electric utility systems and within customer facilities. This database management system contains a variety of power quality case studies, results from numerous EPRI power quality projects and evaluations, and additional reference information. It can also be customized to contain utility-specific power quality information. Altogether, the PQ Database maximizes power quality engineering productivity, establishes a corporate knowledge base, streamlines and automates power quality processes and tasks, and increases the value of utility services to customers.

In addition, we use the PQ Database to document and track each national and major account customer inquiry. (Other customer power quality inquiries are logged in a less-detailed database.) We then perform a quarterly analysis of the database statistics to evaluate our power quality process and plan future activities.

By supporting our efforts to produce well-documented management reports, target essential research and development activities, and plan value-added customer education programs, the PQ Database has become a vital force in the overall power quality process at Duke Power. ■

Standards Update

by Tom Key, EPRI PEAC

This column serves as an open forum on power quality standards activities and developments. Please send your comments to *tkey@ieee.org* by e-mail.

In past *Standards Updates*, we have compared and contrasted international power quality standards, with a particular focus on the standards activities of Europe and North America. This column addresses recent trends toward harmonizing international power quality standards.

The Need to Harmonize

Today's extensive international communication links and alliances define a worldwide marketplace for modern business operations. Electrical compatibility standards will play a pivotal role in the success of many global business relationships involving electric equipment. However, with different standards bodies addressing the same compatibility issues—and in some cases regulating the same electric power parameters in different ways—there is a real need to harmonize power quality standards.

Electric utilities will play a key role in this effort. With the technical expertise they provide and the potential gains they can make in a competitive, deregulated market, who better to interpret and implement power quality and electromagnetic compatibility (EMC) standards for the end-user? End-users are expected to have a manifest interest in international standards that affect the operation of their factory equipment and the trade of their products.

Major International Standards Bodies and Selected Power Quality Subgroups

Organizations	Role	Nature of Participation
Institute of Electrical and Electronics Engineers (IEEE) Standards Coordinating Committee on Power Quality (SCC 22) Power Engineering Society (PES) Industrial Applications Society (IAS) Electromagnetic Compatibility (EMC) Society	I, T	Qualified Individuals
International Electrotechnical Commission (IEC) Technical Committee on Norms for Voltage (TC 8) Technical Committee on EMC (TC 77)	I	National Committees
International Special Committee on Radio Interference (CISPR)	I	Nations and Organizations
International Union of Producers and Distributors of Electrical Energy (UNIPEDE)	I	Utility Industry Representatives
Information Technology Industry Council (ITIC) (formerly CBEMA)	I	Information Technology Equipment Manufacturers
Canadian Standards Association (CSA)	I, N (Canada)	Industry Representatives
European Union Standards Organization (CENELEC)	R	National Appointed Experts
American National Standards Institute (ANSI)	N (USA)	Professional Organizations
Underwriters Laboratories (UL)	N (USA)	Industry Representatives
National Electrical Manufacturers Association (NEMA)	N (USA)	Electrical Manufacturers
National Fire Protection Association (NFPA) (National Electrical Code)	N (USA)	Selected Individuals
National Institute of Standards and Technology (NIST)	T	Government Professional Staff
International Conference on Large High-Voltage Electric Systems (CIGRÉ)	T	Individual and Collective
International Conference on Electrical Distribution (CIRED) Study Committee on Power System EMC (CE 36) Joint Working Group (CIGRÉ and CIRED 36.05, CIRED 2) on Power Quality (CC02)	T	Individual and Collective
International Union of Electro-Heating (UIE) Working Group on Power Quality	T	National, Individual, Corporate

I = international standards development, R = regional standards development, N = national standards development, T = technical support of standards.

Obstacles to Face

Given that there are many good reasons to harmonize standards, it is helpful to recognize some barriers. For one, as the table shows, the Institute of Electrical and Electronics Engineers (IEEE) in New York City and the International Electrotechnical Commission (IEC) in Geneva have very different roles and memberships. While IEC derives strength and stability from its role and structure of member nations, IEEE remains more responsive to ideas generated from an organization of individuals in the electrical engineering profession.

Another barrier to harmonization is that IEC has generally ignored the concept of power quality in favor of EMC and voltage quality. This difference has created a rather formidable list of differences in technical committee structure, standards types, and terminology. For example, the IEC Technical Committee on EMC (TC 77) creates *Basic, Generic*, and *Product* standards, while IEEE's various societies are developing *Standards, Recommended Practices,* and *Guides*.

In support of harmonization is the fact that electrical environments and a growing base of end-user

equipment are the same around the world, irrespective of terminology. A *dip* in Spain or a *sag* in the United States is likely to have the same effect on the productivity of a manufacturer in either country.

Two Cultures to Merge

Currently, IEEE has a number of power quality standards under development by specific working groups in several societies. In fact, so many activities are in process that IEEE has established the Standards Coordinating Committee (SCC 22) to oversee them, with François Martzloff of the National Institute of Standards and Technology as chairman. EMC activities in IEEE are generally kept separate from power quality activities.

In IEC, on the other hand, power quality is looking for its place. It received some direction last year when the IEC Committee of Action approved a recommendation to undertake work on power quality as part of TC 77. But, exactly how to integrate power quality in IEC remains an issue.

France and the United States have each submitted proposals to develop power quality measurement methods. The French proposal mirrors the approach of the International Union of Producers and Distributors of Electrical Energy (UNIPEDE), nominating Roger Ott of Electricité De France (EDF) as project leader. It defines voltage, covers low-frequency situations, and implies that compliance with a European standard may be included. The U.S. proposal, which nominates Martzloff as project leader, refers to IEEE Standard 1159 for monitoring power quality. It emphasizes overall power quality rather than merely voltage quality and equipment compatibility.

Although these differences may be interesting, they may not be so important. TC 77 has officially recommended merging the French and U.S. proposals before any new work is begun. Both proposals seem to share the same goals of obtaining compatible, comparable, and consistent results in the measurement of power quality parameters.

Once this merger is accomplished, perhaps the next step will be to better harmonize technical issues of EMC with power quality since, in fact, the electromagnetic spectrum is unified and continuous. The high-frequency experts of the International Special Committee on Radio Interference (CISPR) and the IEEE EMC Society might work more with the power quality experts supporting IEC and IEEE to harmonize high- and low-radio-frequency standards. This additional dialogue and harmonization will be needed to address the growing involvement of electric utilities in communications systems as well as the increasing number of appliances that involve all aspects of power, electronics, communications signals, and controls. ■

Hotline Highlights

Problem: PEAC consistently receives hotline calls from member utilities regarding digital clocks that run fast. In some cases, PEAC has tracked the problem to arcing in the utility system caused by faulty distribution equipment such as vacuum switches. However, most cases are due to an increasingly common household appliance—the electronic air ionizer. Normal operation of the ionizer creates voltage oscillations and notching, causing some digital clocks to gain time. This occurs because digital-clock circuitry around the world counts these voltage disturbances as additional cycles.

Utilities are also identifying new sources of disturbances to digital clocks. In a recent case, Steve Don, staff engineer at Grand Valley Power in Grand Junction, Colorado, called PEAC about fast-running clocks at some of its customers' homes. The utility conducted a power quality investigation and isolated the problem to a single residence. This time the offending equipment was compact fluorescent lamps, installed in socket-type photocell switches. After testing the lamps and photocells, utility engineers were able to duplicate the problem. They found that the compact fluorescents and photocells individually did not impact the clocks, but in combination they did.

Solution: One easy solution to all of these interactions would be for clock manufacturers to incorporate immunity to voltage oscillations and notches into their product designs. PEAC engineers have demonstrated that the addition of a high-frequency filter in the timing circuit of the clock will solve most interactions. PEAC is also assisting an international clock manufacturer who wants to include built-in immunity in models that are susceptible to these voltage disturbances.

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

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minimum levels of power quality, and customers must not exceed maximum levels for emissions to the system. If customers exceed their limits, they may be required to find a mitigation solution, especially if they impact the quality of power delivered to other customers. Both limits are determined at the national level and approved by public authorities. They provide equal or better power quality than values given in CENELEC Standard En 50 160 and International Electrotechnical Commission Standard 1000-2-2.

The table spells out the levels of quality EDF guarantees to medium-voltage customers in 1997. It also shows the customer commitment required. When EDF exceeds the indicated quality threshold levels—except for harmonics, which will be added to the contract in 1998 or 1999 and are included as an informative clause—the customer may claim compensation for damages and losses incurred.

1997 EDF Criteria for Medium-Voltage Customers

Power Quality Parameter	EDF Annual Commitment	Customer Commitment
Scheduled Interruptions (e.g., for Work on the System)	Number ≤ 2 Duration ≤ 4 Hours	None Required
Long Interruptions (>3 Minutes)	<10,000 Inhabitants: 6	None Required
	10,000< <100,000: 3	
	>100,000, Except Cities: 3	
	Cities >100,000 and Paris Suburbs: 2	
Short Interruptions (1 Second < <3 Minutes)	<10,000 Inhabitants: 30	None Required
	10,000< <100 000:10	
	>100,000, Except Cities: 3	
	Cities >100,000 and Paris Suburbs: 2	
Voltage Variations (RMS Variations)	± 5% Contractual Voltage	None Required
	With Contractual Voltage= ± 5% Nominal Voltage	
Voltage Fluctuations and Flicker	Probability Long-Term ≤ 1 (Measured per IEC 1000-4-15)	Step Voltage Changes ≤ 5% Contractual Voltage Probability Short-Term ≤ 1 (IEC 1000-2-2)
Negative Sequence Imbalance	Ratio of the Negative Sequence Imbalance ≤ 2 %	Ratio of the Negative Sequence Imbalance ≤ 1% (If Apparent Short-Circuit Power >40 MVA)
Frequency	50 Hz ± 1%	None Required
	50 Hz + 4/-6% (Island Systems)	
Harmonics (Informative Clause)	10-Minute Harmonic Voltage Values: Standards CENELEC En 50 160 and IEC 1000-2-2	10-Minute Harmonic Current Values: Limits Defined as a Function of Harmonic Order by Contract Terms
Customized Version	Customized Thresholds	None Required
Short Interruptions	Duration May Start at 600 ms	
Voltage Sags	Sags >600 ms and >30% Depth	

EMERAUDE consists of three different commitment packages:

1. The "Basic Contract With Standard Quality Thresholds" is used for EDF service to a majority of medium-voltage customers. This commitment to quality is available to customers at no additional charge. For a one-year period, it covers specified levels of power disturbances from both utility and customer under normal utility operating conditions. Each year, four regional thresholds for interruptions are set according to the population densities of four areas of France. The success of offering standard quality thresholds has been significant: At the end of 1996, more than 40,000 contracts had been signed.
2. The "Basic Contract With Customized Quality Thresholds" is for customers whose operations are sensitive or potentially sensitive to power disturbances. This contract provides a more comprehensive guarantee, allowing the threshold number of short power supply interruptions and voltage sags to be determined by customer requirements. The customized contract, which can be established for terms longer than one year, costs about $1000 per year if the contract covers voltage dips (sags)

Photo courtesy of EDF/La phototheque EDF

Partnerships and contracts are becoming prerequisites to the success of the utility-customer relationship. EDF has developed contracts that incorporate utility guarantees on power quality as well as customer limits on emissions into the public power supply system.

and about $500 if it does not. This fee pays for EDF's installation of on-site monitoring equipment and the production of a yearly report, both of which help keep customers apprised of their power supply and equipment characteristics. At the end of 1996, about 1000 contracts had been signed, mainly by high-voltage customers.

3. The *Réseau Plus* Contract guarantees maximum yield for customer installations with very sensitive processes demanding high levels of power quality. As part of this contract, EDF conducts studies when critical improvements to the power supply system become necessary. EDF and the customer share study costs, depending on the requirements of the customer, the characteristics of the network, and the ratio of disturbances generated by the customer and EDF. The studies generally have a dual purpose: to enhance the utility power supply system, and to make customer installations less sensitive to disturbances.

To ensure the broad implementation of *EMERAUDE*, EDF is developing a new electronic monitor, which can be installed at the customer's point of delivery to characterize and record power disturbances such as long and short interruptions, voltage dips, overvoltages, and rms voltage variations. This monitor will provide EDF with objective figures and statistics for use in customer reports on the quality of power delivered. It will also significantly reduce the costs of data collection and analysis.

Power Quality Services

In addition to *EMERAUDE*, EDF offers a variety of power quality services to large and medium- sized customers.

The *FIABELEC* service is for customers who want to make their electrical installations less sensitive to power disturbances. It ensures power quality in harmony with customer requirements. The cost of the service depends on the complexity of the problem to be solved, customer requirements, and network characteristics. Jointly provided by equipment contractors and more than 100 local units of EDF, the service includes

- diagnosis of customer installations;
- technical and economic studies of suitable solutions;
- equipment operation and maintenance;
- commissioning of power conditioning equipment; and
- equipment performance guarantee, which includes an indemnity in case of failure.

PREVENANCE is a free service that arranges for EDF to consult with customers about the best dates and times to perform maintenance and improvement work on the power supply network. The *ECHO RESEAU* service, also free of charge, allows EDF to provide information about the quality of their power supply to customers planning factory construction or expansion projects.

The enhancement and customization of the *EMERAUDE* contract and associated power quality services is an ongoing process at EDF.

EPRI R&D Corner

Presently, design standards do not exist for the nearly 50 manufacturers supplying adjustable speed drive (ASD) equipment worldwide. As a result, ASDs can have significant variations in performance, thus impacting system compatibility levels between customers and utilities. (See *PQ Database Gets a Workout*, page 5.)

To address this problem, several tasks of the EPRI PEAC System Compatibility Research Project are defining, under controlled testing conditions, the characteristics of ASDs ranging in size from 5 hp to 150 hp. Working in partnership are major ASD equipment manufacturers representing almost 80% of the global drive market; Hydro Quebec's Laboratory of Electrochemistry and Electrotechnologies (LTEE); Eskom's ASD Laboratory at Wits University in Johannesburg, South Africa; Clemson University in South Carolina; and 21 EPRI-member utility sponsors.

To quantify ASD operation, the rms values of input/output voltages, currents, and powers are measured under varying torque-speed loads. Additional tests—such as dynamic voltage sag, momentary power interruption, and steady-state emissions—document the envelopes of performance achieved by the ASDs. Results allow project participants to assess whether ASDs can meet mechanical-process and electrical-interface requirements—*before* equipment installation.

Building on the knowledge and experience gained from these efforts, PEAC and its international partners are developing the International ASD Immunity Initiative to standardize ASD power quality testing and reporting criteria. The initiative will provide access to ASD test results and applications experiences from such utilities as Eskom in South Africa, EDF in France, and ELFORSK in Sweden. One goal of the partnership will be to establish a network for testing ASD emissions and immunity. Another will be to write expanded ASD test protocols and performance specifications and have them integrated into international ASD design and performance standards. In addition, ASD research results will be shared with industry organizations like the National Electrical Manufacturers Association, Subcommittee 7, to develop voltage sag performance criteria for ASDs.

For technical questions about ASD-related tasks and the International ASD Immunity Initiative, contact Arshad Mansoor at (423) 974-8378 or *amansoor@aol.com* by e-mail. For investment information on tasks, contact Gene Sitzlar at (423) 974-8314 or *gsitzlar@pqac.com* by e-mail.

With today's customers demanding higher levels of power quality, the utility believes partnerships formalized in power quality contracts are key to meeting those needs. ■

An English translation of the EDF *EMERAUDE* ("Emerald") contract is available free-of-charge to *Signature* subscribers and members of the EPRI Power Quality Target. To order your copy, contact the EPRIAMP Customer Assistance Center at 1(800) 4320-AMP or *ecac@epri.com* by e-mail, and request *Signature* "Special Report" No. SSR97-01.

Detroit Edison: Continued from page 1

Michigan from Detroit Edison.

Along with energy price discounts, on-site energy service personnel, and a customized demand-side management program, the SMCs contain unique service guarantees for limits on sustained and momentary interruptions. Guarantees are also being developed for voltage sags.

Why Service Guarantees?

Detroit Edison has worked closely with the "Big Three" for more than 10 years to deliver power quality that accommodates the special characteristics of the auto industry. These include a heavy reliance on computerized information and control systems in the powertrain, assembly, and stamping plants. Momentary interruptions to these sensitive systems can disrupt production for two hours or longer, resulting in broken tooling, damaged parts, lowered productivity, and lost sales. Voltage sags can have a similar effect.

The intent of the SMC service guarantees is straightforward: to reduce the number of power disruptions to auto plant operations. The guarantees establish a target level of power quality required by the customer, while providing financial and contractual incentives for Detroit Edison to meet the standard.

How They Work

Built-in flexibility allows the structure of the service guarantees to vary according to customer needs. For example, Ford wanted to establish its targets by type of plant. As the table shows, the total target for the company's 29 plants is no more than 18 interruptions across five groups. Each interruption above the target for a group results in a prenegotiated payment to Ford by Detroit Edison. In addition, to meet Ford's continuous improvement goals, the targets decrease annually by 5%, rounded to the nearest whole number.

1995 Target Interruptions for Ford Motor Company Auto Plants

Group	Number of Plants	Target
Powertrain	4	2
Assembly and Stamping	6	3
Components	8	9
Other	10	3
Affiliates	1	1
TOTAL	29	18

In the case of General Motors and Chrysler, both have 13 plants covered by service guarantees. Each plant has a fixed annual interruption target of either zero or one and a payment amount for every interruption above the target. If a plant had no interruptions in the three years preceding the guarantee, the target is zero; otherwise, the target is one. The payment amount is negotiated to represent the relative impact of an interruption on the plant and provides a financial incentive for Detroit Edison to meet the targets.

To reach its power quality goals, Detroit Edison is utilizing a wide variety of tools, including "best-feed" service, parallel operation, helicopter line patrols, and infrared line inspections. Perhaps the most interesting tool is the static transfer switch, which is the subject of a joint research project by Ford, Detroit Edison, and EPRI. Installed at the customer's site, this switch is able to detect the onset of an interruption or voltage sag and transfer customer equipment to another electrical source. It completes the transfer so quickly that the interruption or sag does not affect the customer equipment. The switch serves Ford's Sheldon Road plant in Plymouth, Michigan, and early results indicate that it may be effective at other facilities with similar characteristics.

Building on the success of the interruption guarantees, Detroit Edison and the auto companies are now working together to develop service guarantees for voltage sags. These guarantees will use the Institute of Electrical and Electronics Engineers Standard 446-1992 voltage tolerance envelope (CBEMA curve) to define the expected voltage sag limits of customer equipment. All parties are presently sharing installation costs for equipment to provide the data needed to establish and administer the guarantees. Detroit Edison marketing, engineering, and planning personnel, together with auto company representatives, are using the collected data to set voltage sag targets and payments.

Service guarantees offer utilities an innovative way of using power quality to meet customer needs. Detroit Edison intends to remain the energy supplier of choice for the

Calendar Notes

Next year, PQA Conferences will be held in two locations:

PQA'98 North America
Arizona Biltmore, Phoenix, Arizona
Tutorials: June 8, 1998
Conference: June 9–11, 1998

PQA'98 South Africa
Cape Sun International Hotel, Cape Town
Conference: November 9–11, 1998

For more information, contact Lori Adams at (415) 855-8763 or *ladams@epri.com* by e-mail.

Eskom: Continued from page 2

4. Both parties negotiate and agree upon a monthly charge for the required performance level.
5. Eskom purchases, installs, and commissions the necessary power conditioning equipment at the customer site.
6. Eskom performs maintenance for the duration of the contract.

Service contracts are also offered, which provide the consulting and reconfiguration support listed in the first four steps above. Since the commencement of *Sine~On*, Eskom has entered into three premium-quality power contracts and more than 100 service contracts. In addition, numerous new premium-quality power contracts are in the process of being negotiated. Customer and consultant acceptance have been very positive, assisted by the fact that a set of minimum quality-of-supply standards were recently established for South Africa as a whole.

Eskom recognizes that an ideal power quality level is probably not possible. However, by taking the initiative and risk up front, the utility has demonstrated that practical power quality solutions to complex problems in large and small customer plants can be economically achieved. These experiences are being shared through an international cooperative agreement with PacifiCorp in the United States and its subsidiary, Powercor, in Australia. ■

The *Eskom Power Quality Handbook* is available free of charge to *Signature* subscribers and members of the EPRI Power Quality Target. To order your copy, contact the EPRIAMP Customer Assistance Center at 1(800) 4320-AMP or *ecac@epri.com* by e-mail, and request *Signature* "Special Report" No. SSR97-02.

PQ Pointer

Lessons Learned from Plant-Scale Power Conditioner Installations in the United States

1. **Make sure factory tests match real-life conditions**. A lithography plant in Georgia experienced upsets to its printing process during voltage sags. The serving utility installed a battery and dc-ac converter system at the plant's service entrance to prevent tripping of adjustable speed drives and programmable logic controllers during sags. The system also incorporated a static switch to transfer the entire plant load from the primary utility source to the battery back-up source. The system performed as intended during simple three-phase sags and power-loss tests at the factory. However, during field trials, it identified the loss of two utility feeder phases as a phase reversal, causing it to reverse rotation. A software change corrected this misinterpretation by the system.
2. **Consider all voltage sag characteristics in mitigation device ratings**. A utility in North Carolina installed a dynamic voltage restorer in its feeder to a plant for extruding and spinning polypropylene fibers. The device is intended to act as a fast regulator, boosting remaining voltage and compensating for low voltage during sag events. However, tests revealed that a phase shift occurring during the sag also needed to be considered in the restoration voltage. Depending on the degree of shift, a larger voltage component would be needed to restore voltage. For example, a 50%-deep sag at 30-degree phase shift increases the required restoration voltage to 58% of the rated voltage. At 180-degree phase shift, the 50% sag requires restoration voltage of 150%.
3. **Watch the small details in large systems**. A total energy system designed to back up a California semiconductor manufacturing plant combined an ac machine, induction and magnetic couplings, and a quick-start diesel generator. On one occasion, during full production at the plant, an interruption of utility power called the energy system into service. The system started up successfully and transferred plant load. However, after a few minutes, a clogged fuel line acted to shut down the system—and the plant.

CEPEL: Continued from page 4

100 hp. Its main objective is to optimize the internal parameters and settings of ASDs, allowing more efficient and robust operation.

CEPEL has also developed a comprehensive collection of software programs and diagnostic equipment for use in its power quality studies. These products are available for purchase by utilities, customers, manufacturers, and engineering companies, with discounted prices for CEPEL members.

Software includes: ANAFAS, to simulate simultaneous faults in a util-ity system; HARMZW, to compute utility system frequency scans and help define models for use in frequency correction; and NH2, to calculate generation and transmission reliability in large hydrothermal power systems. Diagnostic equipment includes capacitive potential dividers, which permit accurate measurement of harmonics above 1 kHz as well as switching transients. This product for measuring utility system voltage can be customized to meet specific system requirements.

Plans for expansion at CEPEL include the development of software programs to diagnose power quality. An important use of this software will be to support a project to monitor power quality throughout the entire network of Brazilian utilities. This project will be similar to EPRI's Distribution Power Quality work in the United States. ■

Point of View: *Continued from page 1*

If this sounds like an opportunity to capture a market that is ripe for premium services, don't be misled. The next presenter from the semiconductor industry stated: "Please don't offer us a better quality of power at a higher price. We won't accept it. Our customers ask us for higher-quality products at a lower price, and we meet their need while cutting our costs. We want the same from utilities." Food for thought for all of us in the utility industry.

Looking ahead, what will we offer as customer technologies become increasingly sophisticated? This type of discussion will be continued in September at Part Two of the semiconductor workshop series. Stay tuned!

Marek Samotyj, Manager
Power Quality Target

Con Ed: *Continued from page 3*

and 45 seconds of ride-through protection for sensitive loads during voltage disturbances. It isolates critical equipment—such as computer workstations, file servers, data centers, and telecommunication systems—from the effects of local voltage transients, harmonic interferences, and other power supply abnormalities produced by disturbing loads within the facility. And, to ensure proper grounding of tenant equipment at all times, the arrangement includes isolated grounding circuits, with neutral bonded to ground at the output of each motor-generator.

Serving Customers

Con Edison's premium-power system at the IT Center eliminates the need for tenants to individually install and maintain costly and space-consuming uninterruptible power supply equipment. In addition, technical support from the utility backs up the center's existing on-line supervision and 24-hour engineering services.

By leveraging its involvement with New York City's IT Center, Con Edison intends to become the region's premier source for power quality and power electronics information and services. The utility is working on behalf of customers to facilitate the transfer of power quality and power electronics technology. Such activities also encourage dialogue among equipment and component manufacturers, service organizations, architectural and engineering firms, and electrical contractors.

In addition, Con Edison is working in conjunction with the EPRI Power Quality Target to evaluate the quality of power served at the IT Center. This three-year research project includes monitoring and analyzing power quality at the center and evaluating the performance of the Written-Pole motor-generators.

Because information technology is a fast-growing industry, Con Edison believes the IT Center concept has tremendous potential. Customers pay an average rent and little or no more on their utility bills to receive premium-quality power in state-of-the-art facilities. That is the way of the future. ■

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Electricity is increasingly recognized as a key to societal progress throughout the world, driving economic prosperity and improving the quality of life. The Electric Power Research Institute delivers the science and technology to make the generation, delivery, and use of electricity affordable, efficient, and environmentally sound.

Created by the nation's electric utilities in 1973, EPRI is one of America's oldest and largest research consortia, with some 700 members and an annual budget of about $500 million. Linked to a global network of technical specialists, EPRI scientists and engineers develop innovative solutions to the world's toughest energy problems while expanding opportunities for a dynamic industry.

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