Developing a Utility/Customer Partnership To Improve Power Quality and Performance

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Abstract

Many industrial and commercial electric customers now require a higher level of power quality due to increasing sensitivity of sophisticated process controls and the growing reliance on computers. These customers are especially sensitive to momentary voltage sags caused by remote faults on the transmission system or on parallel feeder circuits. They are also applying more and more equipment that can cause harmonic distortion problems (e.g. adjustable speed drives).

Determining the optimum supply system and customer electric system characteristics for these sensitive customers requires a careful evaluation of different alternatives. Power quality can be improved through system-side solutions, customer service entrance solutions, power conditioning for selected equipment within a facility, or improved specifications and equipment design. All of these alternatives have costs and associated benefits.

Many times, the customers do not have the expertise or time to focus on identifying, characterizing, and solving power quality problems. This is an area where the utility can provide valuable services for the customer in a partnership arrangement. The electric supplier has an advantage in characterizing and solving power quality problems because he/she can take a system perspective to solving the problem. This includes evaluation of the supply characteristics and the power quality requirements of all customers on the system, rather than the requirements of one particular process.

This paper describes the types of services that the electric supplier can provide in the partnership arrangement and a procedure for performing economic evaluations of different power quality improvement alternatives using a systems approach. Solutions identified can be implemented at the design stage or as retrofits as part of the overall power quality services offered by the utility.

Utility Power Quality Services

Power quality services fall into three major categories:

1. **Services to help avoid power quality problems at the planning/design stage.** It is always best to avoid power quality problems before they occur. This can be accomplished by understanding the environment, developing equipment specifications for compatibility, and designing facilities to allow convenient power conditioning for critical and sensitive equipment.
2. **Services to help solve power quality problems.** These services are designed to assist in understanding the causes of problems and developing optimum solutions. The services can include the investigations, recommending solutions, and actually implementing solutions.
3. **Services to verify performance and provide ongoing information.** Information services can help customers identify equipment problems quickly, characterize problems when they occur, verify the proper operation of power conditioning equipment, and provide the basis for future equipment specifications.

Under these three main categories, there are many types of specific services that can be offered to help customers improve the efficiency and reliability of their operations. Examples of these services are indicated in Figure 1 and described in the subsequent sections of this paper.

Voltage sags and momentary interruptions are the most important power quality variations affecting many industrial and commercial customers. The descriptions of specific services focus on the applications to help solve problems with these power quality variations. The concepts are equally applicable to problems associated with capacitor switching transients or harmonic distortion levels but the specific types of investigations, equipment, and solutions would be different.

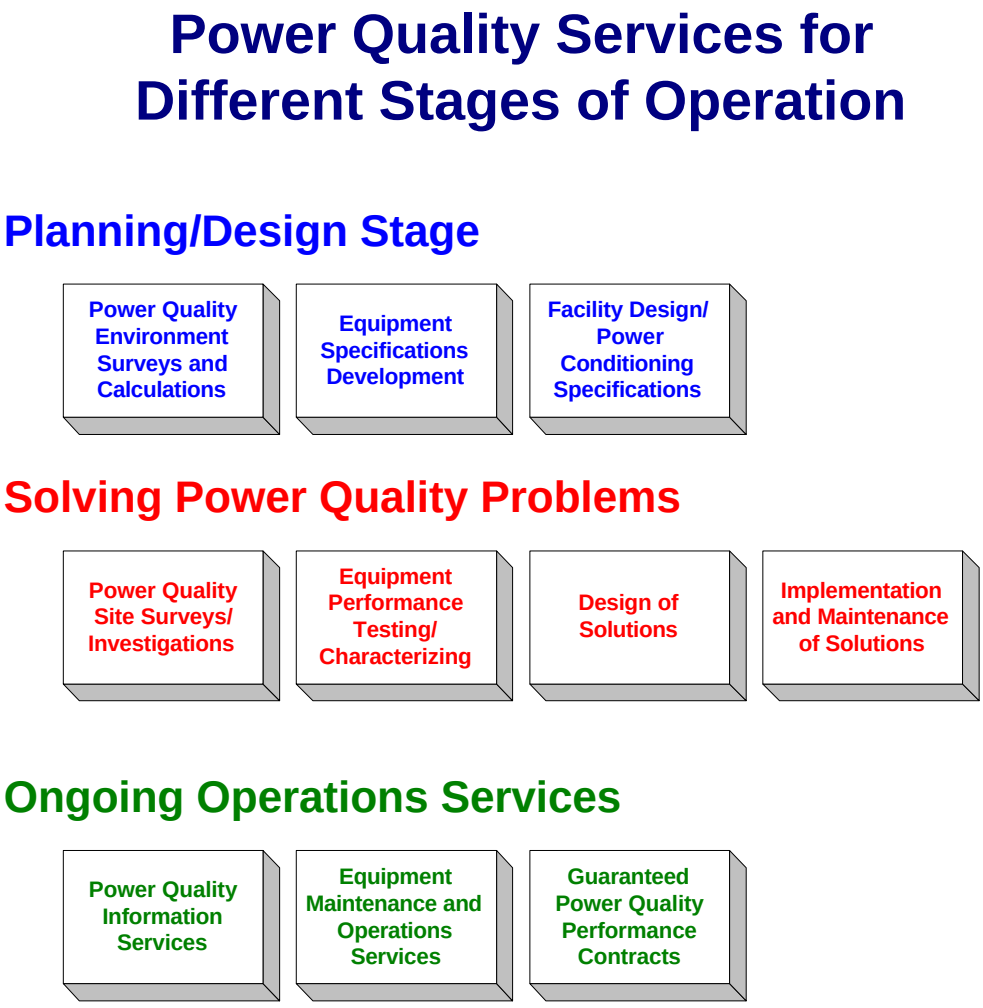

Figure 1. Examples of power quality services that can be offered by the electricity supplier.

Characterizing the Power Quality Environment

The first important task in establishing compatibility between the electrical supply and the facility operations is to characterize the expected quality of the supply. Standards like IEC 1000-2-2 provide some basic guidelines for the levels of power quality that can be expected but these specifications are inadequate to actually evaluate the economics of providing power conditioning to all or parts of a facility.

The electricity supplier can characterize the expected power quality at the customer location in much more detail. Switching transients can be evaluated with simulation tools; harmonic distortion levels can be estimated based on other harmonic producing loads in the area and the system response characteristics; and the expected voltage sag performance can be determined from historical data, long term measurements, and short circuit simulations. Figures 2 is an example of a typical chart used to illustrate the expected voltage sag performance at a customer location in terms of the sag magnitude. Figure 3 is an example of a chart type that combines the magnitude and duration data for the expected performance – this is the format recommended by the IEEE P1346 Working Group on Compatibility with Industrial Process Equipment.

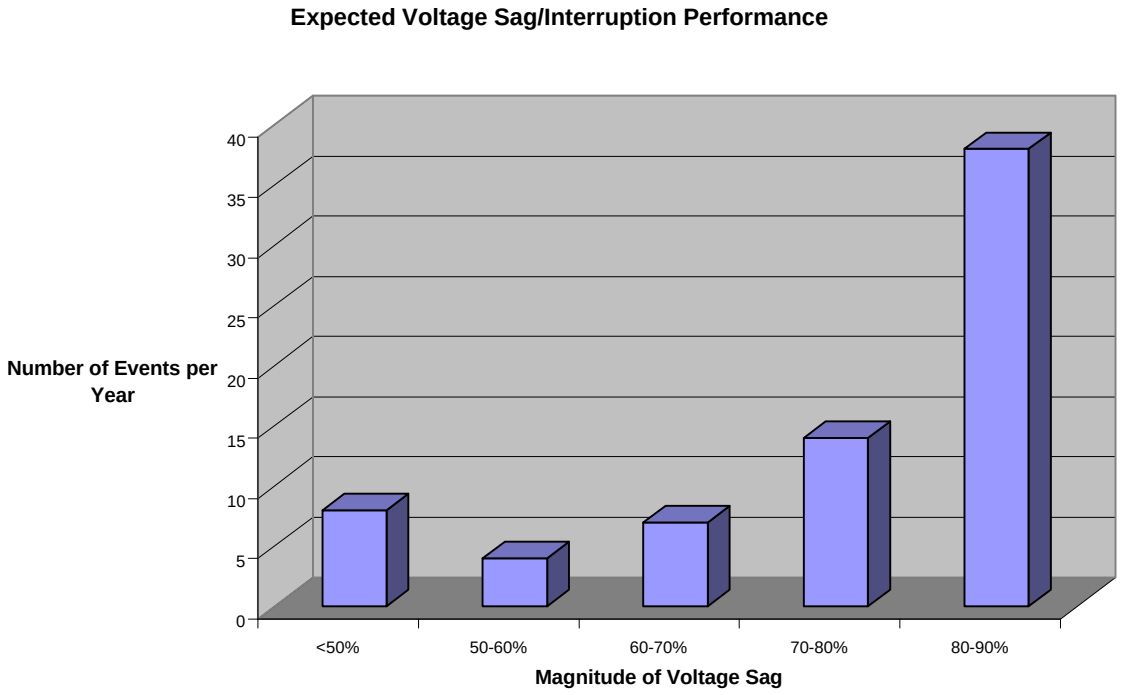

Figure 2. Example voltage sag performance bar chart.

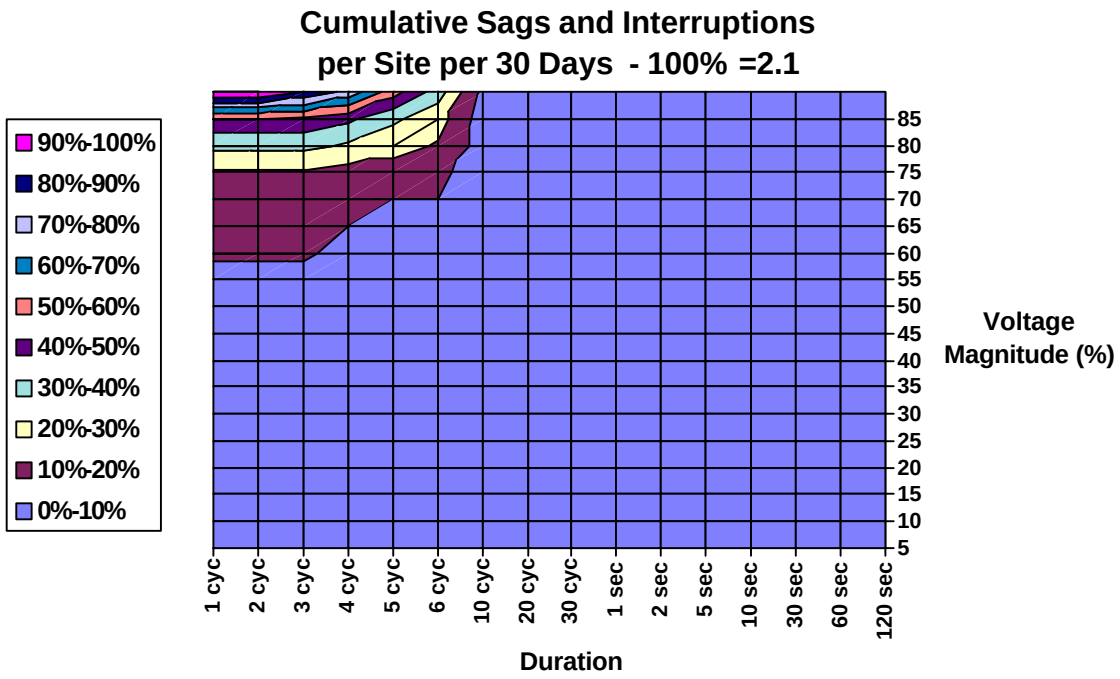

Figure 3. Example of contour plot of expected voltage sag performance in terms of magnitude and duration.

Developing Equipment Specifications

With an understanding of the expected power quality environment, it is possible to develop equipment specifications that will help assure reliable operation of the overall facility. The electricity supplier can help translate the expected performance information into actual equipment specifications. Important categories to consider at all levels of the system are shown in Figure 4. *This figure is from the Power Quality Workbook developed by EPRI with the Bonneville Power Administration.*

Developing Recommendations for Facility Design and Power Conditioning

It is also possible to take the concept of developing equipment specifications a step further and actually participate in the overall facility design. This would include layout of the facility loads to improve power quality performance and to achieve the most economical design for power conditioning equipment. The layout should assure that the facility loads do not interfere with each other (e.g. voltage notching from converters) and should provide convenient grouping of sensitive loads for power conditioning. For instance, process controls will almost always justify power conditioning and a common supply for the process controls can greatly reduce the power conditioning costs.

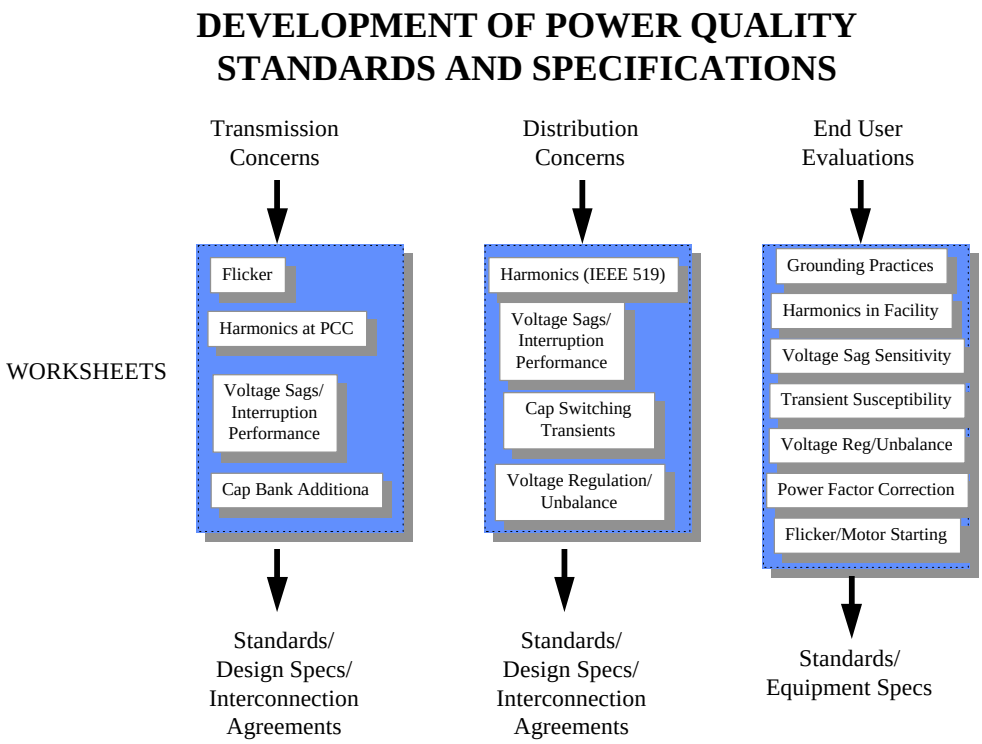

Figure 4. Types of power quality evaluations to consider in developing equipment and performance specifications.

Investigating Power Quality Problems

Once the customer facility is in operation, power quality problems may be encountered. Customers do not usually have the expertise to investigate these problems, identify the causes, and develop options for solving the problem. Electric utilities have been helping their customers investigate these problems that may involve interaction between the supply system and the customer facility for a number of years. Utilities have developed groups of power quality engineers, purchased monitoring equipment, and obtained required analytical tools for these investigations. The need for these investigations will continue, even with improved designs of the facilities for compatibility with the power quality environment. It will continue to be easier and more economical for the electricity supplier to maintain the required expertise and tools to perform these investigations than for each customer to make the large investment required.

The investigations will usually involve problems of compatibility between the supply system electrical characteristics and the power quality requirements of specific equipment or processes. The investigations may require monitoring to characterize both the power quality and the equipment sensitivity. Simulations may be needed for extrapolation to other system conditions and to evaluate possible solutions from a technical perspective. Figure 5 illustrates the general procedure for performing these investigations (also from the EPRI/BPA Power Quality Workbook).

Significant expertise is developing over time by performing a large number of these investigations for a wide range of different customers. *Tools like EPRI's PQ Database can help organize the results of these investigations and provide a starting point for new engineers that require training and background on previous investigations.*

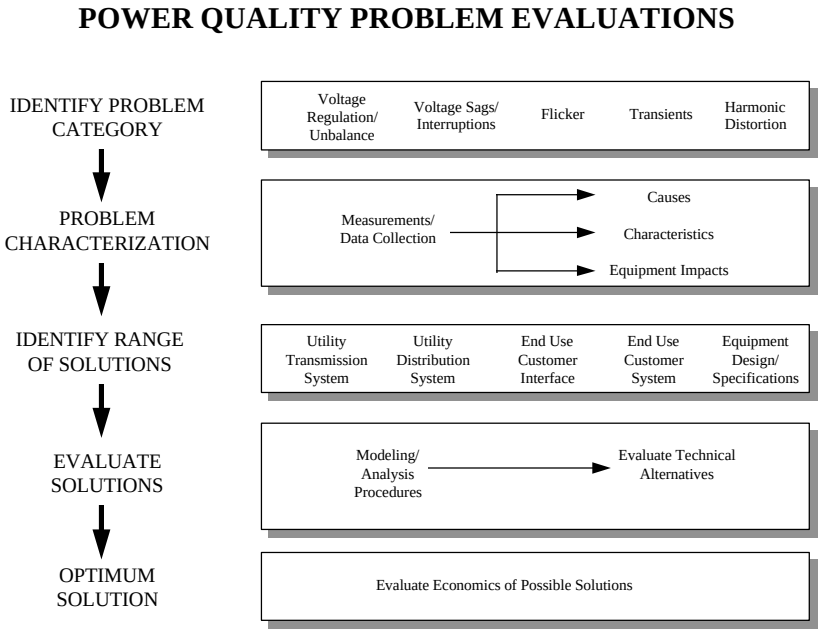

Figure 5. Procedure for evaluating power quality problems.

Testing Equipment Performance

Power quality investigations usually involve a problem with equipment malfunctions during power quality variations. It is difficult to solve these problems without an understanding of the equipment sensitivity to power quality variations. Unfortunately, this information is often not available from manufacturers and, therefore, must be obtained from testing in the field and the laboratory. *EPRI started the Power Quality Test Facility as part of the Power Electronics Application Center to support utility needs for these testing services.* Figure 6 is an example of voltage sag ride through characteristics that can be obtained from laboratory tests. Efforts are under way to provide more complete testing specifications to characterize equipment performance during power quality variations. These are the *System Compatibility* Testing Guidelines.

Designing Solutions

Once the equipment sensitivity is known and the system performance is characterized, possible technologies to solve the power quality problem can be identified. The results of the preliminary power quality evaluations will identify potential compatibility problems and possible solutions that can be implemented for each type of problem (e.g. improved equipment ride through characteristics, harmonic filtering, capacitor switching control). Treating all of the power quality concerns together, it may be possible to design a more economic alternative for providing the required level of power quality. For instance, power conditioning equipment that provides ride through support and harmonic control could eliminate the need for harmonic filters. This evaluation should use a system perspective – the most economical method of solving the problem could be on the utility side of the meter. Only the electricity supplier can really take the system perspective in designing an optimum solution.

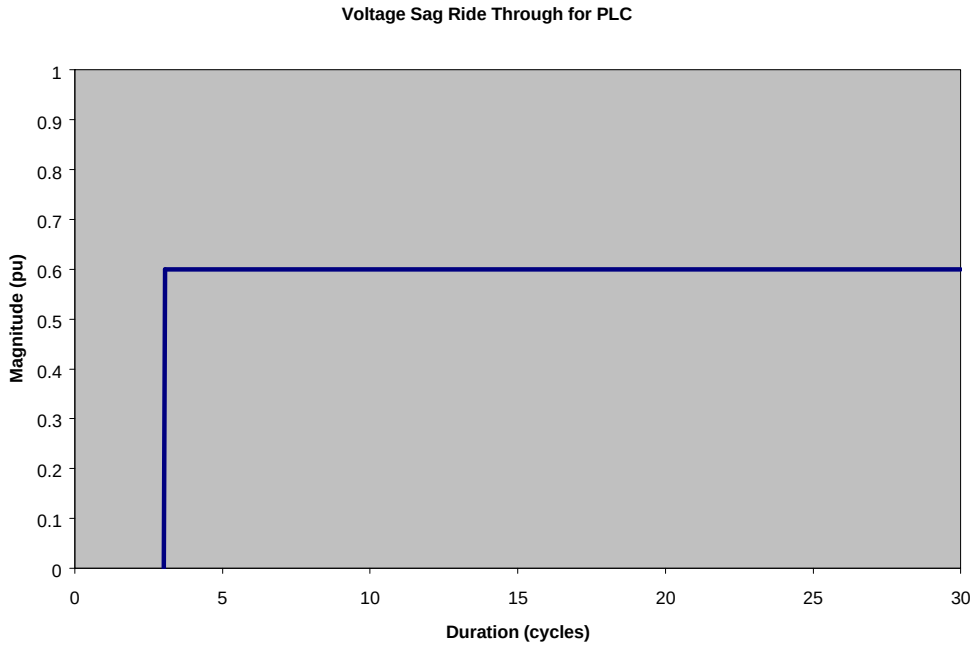

Figure 6. Example of equipment ride through capability based on testing.

Implementing and Maintaining Solutions

It is possible to take the service opportunity one step further and actually implement the solution for the customer. This frees the customer to focus on the job of running his business while outsourcing functions that can be provided more efficiently as a purchased service. The electricity supplier will have to develop staff or contractors for installation of equipment within the customer facilities and for periodic maintenance of the equipment. This is a very important service opportunity for utilities as they look for new revenue opportunities from their existing customer base. There are opportunities for alliances with power conditioning equipment vendors that can spread the risks associated with getting into the business of providing the power quality improvement solutions.

The first important task in establishing compatibility between the electrical supply and the facility operations is to characterize the expected quality of the supply. Standards like IEC 1000-2-2 provide some basic guidelines for the levels of power quality that can be expected but these specifications are

Providing Power Quality Information Services

Once the customer facility is operational, there is an ongoing need for power quality information (often in conjunction with information about overall energy use). The power quality performance information can be provided by the electricity supplier so that the customer does not have to maintain specialized expertise. The information reported back to the customer can be in summary form with a focus on recommendations to improve performance and information verifying proper operation of equipment and the system.

The backbone of a power quality information service will be a power quality monitoring system that can track performance both on the supply system and within customer facilities (e.g. at sensitive loads or power conditioning equipment). *EPRI has developed the PQView program as part of the Power Quality Diagnostic System to help manage the large amounts of power quality data that must be continuously*

collected from around the system. The system allows the utility to provide individual customers with access to the data in the form of summary reports and documentation for individual events via the World Wide Web (Figure 7).

Ongoing monitoring has the advantage of identifying any problems quickly and providing the information necessary to characterize the problem. Many equipment problems can be identified from changes in the power quality levels (e.g. component failures in power electronics equipment cause changed harmonic generating characteristics, switching problems will result in higher transient overvoltages, filter component failures will cause unbalanced harmonic levels, etc.). Over time, equipment sensitivity to power quality variations is characterized in much more detail so that additional power conditioning requirements can be identified and optimized.

Providing Equipment Maintenance and Operation Services

This type of service was described above under installing and maintaining the solutions to power quality problems. The service can be offered as a general service to customers for operating and maintaining power conditioning equipment. The supplier would develop expertise in specific types of power conditioning equipment and can achieve economies in the maintenance of the equipment through larger volumes (spare parts, required equipment for maintenance, ongoing monitoring of performance to identify maintenance needs, etc.). This again frees the customer to focus on the core business.

Providing Guaranteed Power Quality Performance Contracts

The customer might not even be interested in the specific technologies needed to make sure his/her process operate in a reliable manner. All the customer wants is a guarantee that the system will reliably provide the power needed to keep the facility operational. It would be up to the service provider to make sure that the combination of the supply system and any needed power conditioning equipment meets the needs of the specific process involved. This service requires an understanding of the system, the process, the specific equipment in the process, and the types of power conditioning equipment that could be employed. The service would have to be priced based on the level of power quality that must be maintained and the penalties associated with a power quality problem.

Solutions to maintain the required level of power quality can be optimized by the supplier. The options for improving power quality are evaluated at four different levels:

1. Supply system modifications and equipment that affect multiple customers.
2. Service entrance technologies.
3. Power conditioning at equipment locations within a facility.
4. Equipment specifications and design.

The last alternative is ideal for a long term solution but is often not practical when trying to improve the operation of an existing facility.

The customer need for this service and the price he/she is willing to pay will depend on the costs of a power quality problem at the facility and the susceptibility of the process. *EPRI is developing the economic analysis tools to evaluate the economics of different solutions as a module of the Power Quality Diagnostic System.*

Why Should the Electricity Supplier Offer These Services?

Electric utilities have built power quality programs as customer service functions to help customers improve their operations and achieve compatibility with the electric supply characteristics. As deregulation takes hold of the utility industry, what will happen to this theme of cooperation between customers and their electric utilities? Will they continue to have a close working relationship? Will utilities have the same incentives to help customers? Will they be looking to convert all of the services to income-producing opportunities?

There is no question that customers will continue to have problems. Manufacturing processes are more integrated and automation is the name of the game. If any component in the whole process is impacted by a power quality variation, the whole process is interrupted. So, where will customers go for help in the deregulated environment when they are buying power from one electric utility, it is being wheeled across the transmission system of another utility, it is being delivered by a third utility, and it is being metered by someone else?

Maintaining Key Customers

Commercial building operators and manufacturing facility managers will not want to deal with three or more different utilities to get their problems solved. Customers will want to make sure that their power quality issues are handled as part of their overall electricity (or energy) contract. This makes power quality issues one of the areas of differentiation that can help utilities keep their most important customers. For instance, the special contracts that the automotive companies negotiated with both Detroit Edison and Consumers Power include payments for momentary interruptions to the facilities and on line monitoring of all power quality variations to help evaluate the impacts on production. In return, the automotive companies signed long term contracts with these suppliers.

The Energy Services Company

Evaluation of power quality concerns and implementation of power quality improvement technologies are part of a much larger concept that is taking hold throughout the utility industry - the Energy Services Business. Utilities are looking for ways to offer services to their traditional customer base because the margins on traditional electricity sales will become less and less as deregulation takes over. When technologies and expertise are developed to offer a range of services, the services can be offered worldwide, not just in a traditional service territory. The power quality services described in this paper illustrate the range of services that can be integrated into the Energy Services business concept.

Regulation

Power quality will have to be regulated. As deregulation takes over the industry, the temptation to let the level of service and investment in the system deteriorate is obvious. Regulators will want to prevent this be requiring some basic level of quality and reliability. Indices are being developed and standardized to facilitate the characterizing of power quality levels on the system (IEEE 1159-1992 provided a starting point by standardizing the definitions). EPRI recently completed a 2 year monitoring project to provide benchmark indices describing power quality levels on distribution systems in the United States. The Europeans have already started the process with the Euronorms (EN50160) that define levels of power quality that can be expected in a number of important categories (harmonics, flicker, regulation, unbalance, disturbances).

Utilities will have to report power quality performance statistics and make sure that the performance does not significantly deteriorate over time. The regulations governing power quality will be part of the overall

regulations for operating the distribution part of the electricity supply business (often called the lines company). This will require more system monitoring and analytical tools to predict performance as part of the system design process.

The regulations will only address a base level of power quality and will be evaluated on a system-wide basis. They will not change the need for power quality investigations and services that are targeted to individual customers.

What will the Power Quality Program Look Like?

Power quality programs of the future will have a number of very important functions.

- They will coordinate system monitoring and analyses to benchmark system performance, evaluate problem conditions, and prioritize system investments to improve performance.

- They will coordinate with system planning and design groups to include the evaluation of power quality impacts in the system design process.

- They will provide a full range of services for customers both within and outside their traditional service territories. These will include in-plant monitoring services with on-line analysis of performance and recommendations for system improvements. They will install and maintain equipment to improve performance and energy efficiency. They will analyze specific problems and develop solutions and then follow through with actual implementation management.

- They will develop alliances with equipment manufacturers and other service providers in order to offer system solutions to customers and take advantage of quantity discounts. They will develop expertise in these products and services so that there is an added value to the customer.

- The power quality services will be integrated with much larger service packages that will include a full information system for the customer (power quality, energy use, billing information, equipment performance, etc.), energy management functions, and equipment maintenance contracts.

Deregulation will not mean the end of power quality evaluations as an important function within the electric utility industry. On the contrary, power quality is only increasing in importance as competition becomes the standard and utilities look for new ways to service their customer base. *The information, tools, and techniques being developed through EPRI's Power Quality Program provide the basis for developing and providing a complete range of power quality services.*