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Power Quality

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Dina is working at her desk on her office computer. She sends a document to print on her brand new office laser printer. To her surprise, her computer locks up. She reboots the computer and continues to work. A little while later, she sends another document to the same printer. The computer freezes again. Suspecting that there may be a connection, she decides to call the computer support desk and report the problem.

A consultant comes to Dina's office to help but experiences the same problem. He is able to print the document on a different printer on the network without any computer problems, however. No one in the office seems to have a clue as to the cause. Baffled, the staff calls the printer's manufacturer for help. They ask him to call the local utility to report the problem. The next day, a troubleshooter from the utility arrives to take a look at Dina's problem. After monitoring the outlet voltage waveform, and, talking to the company's electricians, the troubleshooter concludes that the newly installed laser printer was creating a voltage dip severe enough to cause the computer power supply to blink.

The problem that Dina encountered with her computer is just one of many similar problems appearing in homes, offices, commercial building and manufacturing plants throughout the industrialized world. This phenomenon is commonly referred to as a power quality problem.

One big reason for the poor power quality incidents we experience is the proliferation of electronic devices. Our voracious appetite for higher efficiency and productivity in the manufacturing sector, comfort and automation in our homes, and efficient lighting systems in commercial installations are driving the market for power electronic devices.

At the forefront of this explosion is the switched power supply. Compared to its predecessor—the linear power supply—it can convert higher power much more efficiently and with a significantly smaller footprint. The switched power supply is found in most of today's computers, fax machines, laser printers, office copiers, etc.

Nonlinear loads

From the electricity consumption perspective, these power electronic devices may be referred to as nonlinear loads. They consume power in spurts and not constantly as a linear load would.

A linear electrical load is made up of resistive, inductive, and/or capacitive elements. Such a load draws a current that is sinusoidal in shape and one that is proportional to the voltage (Fig. 1a). This is because these loads do not depend on the voltage to determine their impedance. Their response, at a given frequency, is completely linear. These loads are not particularly disruptive either to utility networks, other consumers, or the network to which they are connected.

Power electronic loads, on the other hand, do not always follow the well-known Ohm's law. In the presence of a sinusoidal voltage, the current produced is neither sinusoidal in shape, nor is it is proportional to the voltage (Fig. 1b).

Because of the nonlinear relationship between the supply voltage and the load current, these loads are called nonlinear. The nonsinusoidal current consumed is due to the device impedance changing over a complete voltage cycle. When a large number of these devices are connected on the same distribution line, nonlinear currents flowing through the network impedance can, at times, distort the supply voltage waveform. This has the potential of causing severe problems to other loads (discussed later).

So, why was the laser printer interfering with the computer operation in Dina's office? The laser printer was operating from the same branch circuit as the computer. Since, a laser printer consumes a large amount of power when operating, it created a sag in the supply voltage. This caused the downstream computer's power supply to malfunction. The least-cost solution was to reinstall the laser printer on a dedicated branch line.

Problems in a deregulated era

Compounding the problem of the proliferation of nonlinear loads is the reliability problem now plaguing the power service industry. In the past, electric utilities were able to live up to the general expectation of, at most, a few hours of power outage during the year. However, with the dawn of a deregulated era, and with many utilities divesting the extremely competitive power generation business component, many areas in the US are bracing for extended hours of power outages. So far, California has been the hardest hit. In the summer of 2000, an unrelenting heat wave and the economic boom spurred an unprecedented demand for electricity there. With the deregulated power market still in its infancy, wholesale power prices have shot up five to 10 times the normal prices. The

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Independent System Operator, or ISO, which controls about 75 percent of the state's electric power grid for private utilities, declared more than a dozen statewide power shortage emergencies at peak periods of consumption cutting power to large numbers of commercial and industrial users.

The rotating blackouts have been particularly catastrophic to the high-tech industry in the "Silicon Valley" of California. This industry is sensitive to interruptions to the point that they cannot stand more than eight seconds of interruption per year. Without a battery backup, even a 1/60th of one second of interruption can cause enough voltage sag to render a Silicon device worthless during the manufacturing cycle. A shut down of a chip fabrication plant, even for five minutes, could cause delays from a day to a week to get production back up to speed. Millions of dollars worth of business on e-commerce sites can disappear in one second of a power outage. A CNN report estimates that around $5 million (USD) a day is lost based on a 10 second interruption because the whole system has to be shut down to realign the system.

Common problems

Voltage sag is only one of several phenomena defined under the general category of power quality. Other power quality problems related to voltage and current quantities are transients, harmonics, voltage flicker, electromagnetic interference (EMI) and momentary outages.

Not too long ago, power quality was the ability of electric utilities to provide electric power without interruption. Of course, we know better today. Dina's problem laser printer reminds us that electricity consumers also can create poor power quality problems. Today, the term "power quality" encompasses any deviation from a perfect sinusoidal waveform that can results in failure or mis-operation of customer equipment. This includes EMI noise, transients, surges, sags, brown outs, black outs and any other distortions to the sinusoidal waveform. The common symptoms are automatic clock resets, data errors in computer processing, equipment failure, power supply malfunction, system lock-out, adjustable speed drive (ASD) trip-off, programmable logic controller shut down, interference with telecommunications systems, neutral wire overheating, capacitor bank overloading and many other abnormal conditions.

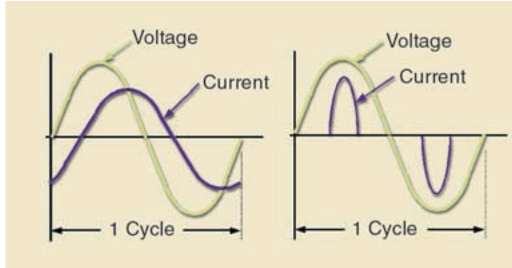

Fig. 1 Voltage and current relationships in (a) linear load, and (b) nonlinear load

The economic impact of poor power quality is also becoming evident. Undoubtedly, the industry that suffers the most from power quality problems is the semiconductor industry. Other industries that rely on "just-in-time" inventory, assembly operations, robotics and automation also bear significant losses to varying degrees from degraded power quality because of production stoppage. When one includes assembly start-up costs (after a down time), lost profits, and overtime labor costs, some staggering figures can be associated with poor power quality. Frost & Sullivan, an independent consulting firm specializing in evaluating technology markets, estimates that voltage disturbances alone cost US industry over $20 billion every year. Table 1 shows estimated losses in various industries per voltage sag event.

Table 1 Impact of voltage sags on industry

Industry	Loss
Paper manufacturing	$30,000
Chemical industry (plastics, glass, etc.)	$50,000
Automobile industry	$75,000
Equipment manufacturing	$100,000
Credit card processing	$250,000
Semiconductor industry	$2.5 million

Power quality disturbances most commonly encountered today fall under the categories listed in Box A. Next, we will show a few examples of how power quality can deteriorate in our normal day-to-day life.

Voltage sag

A voltage sag is apparent when a personal computer re-boots and the screen goes blank, or a process controller inexplicably re-starts in the middle of a long process. A study performed by a major US public utility showed that the overwhelming majority of voltage disturbances, which cause computer shutdowns and process restarts, are short-duration voltage sags lasting one second or less. Disturbances can be caused due to faults on local distribution feeders, or, more commonly, the utility transmission system.

Figure 2 shows a typical radial distribution feeder for delivering power from substations to individual customers represented as loads in the diagram. The figure also shows two of the most common protective devices used in distribution systems, namely, the current limiting fuse and the automatic recloser.

Medium-voltage distribution systems that supply industrial plants, shopping centers, hospitals, schools, office buildings and underground residential service often require fuses for over-current protection. By limiting the let-through energy at the fault, current-limiting fuses assist in limiting or preventing short-circuit damage to other electrical components, such as motors, transformers, capacitors and circuit-protection equipment. In one type of fuse, a wire element inside the cutout melts almost instantaneously over the entire length at

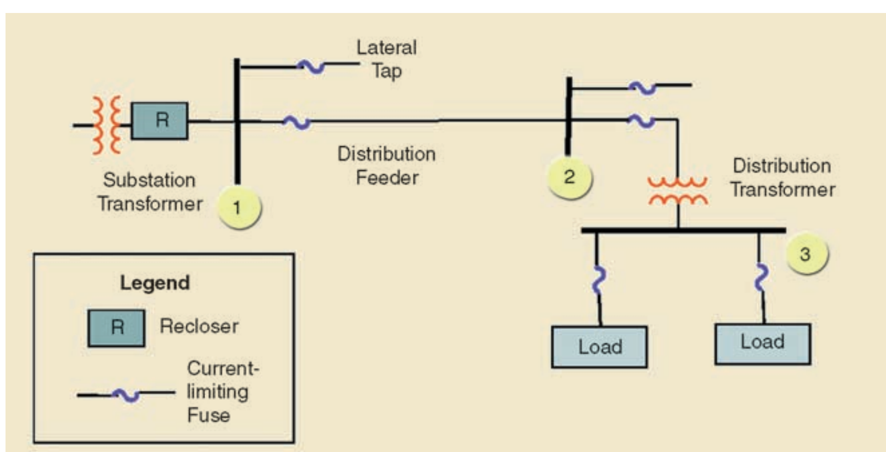

Fig. 2 Diagram showing power distribution from substation to individual loads

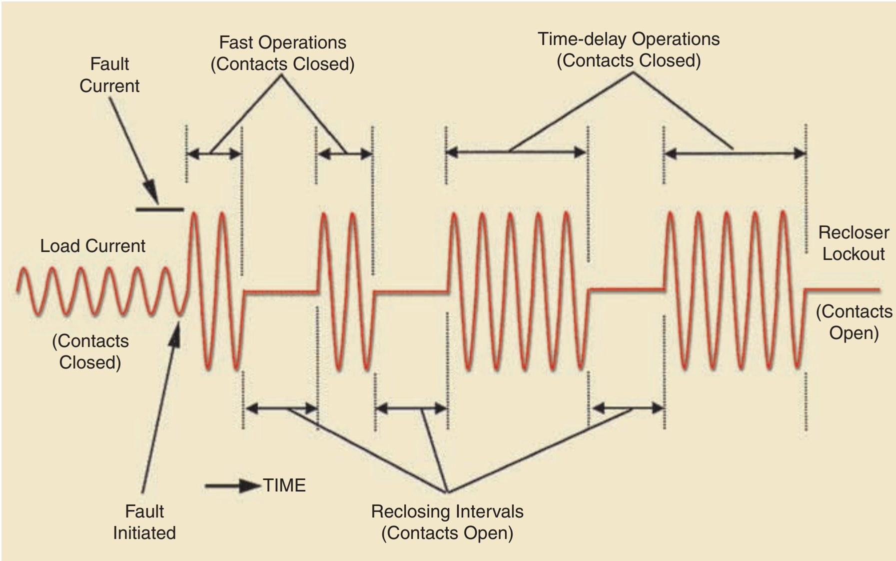

Fig. 3 Typical Recloser Operating Sequence to Lockout (Courtesy: Cooper Power)

various points. The element vapor is driven into sand and condenses. The fuse interrupts the current within one-half cycle and the peak let-through current is only a small fraction of the total available short circuit current.

Automatic reclosers, on the other hand, are small circuit breakers used for clearing temporary faults on a primary distribution circuit. They are normally closed but automatically open when a fault current, at least twice the rated normal current, flows through a series solenoid. When the fault current stops, they are reclosed by the release of a spring that was compressed during the opening, aided by gravity. Distribution class reclosers have an operating cycle that consists of one or two instantaneous openings, followed by one or two time-delayed openings, as shown in Fig. 3.

The reclosing operations are done to clear temporary faults (the majority of faults). If a recloser opens for the fourth time, the fault is of a permanent nature and the recloser locks open. The instantaneous operations are fast enough to prevent the blowing of fuses through which the same fault current is flowing.

Figures 2 and 3 show an example of how momentary interruptions lead to voltage sags during normal utility operations. For a fault on a lateral tap of Fig. 2, the recloser at point 1 will operate to save melting of the fuses in a sequence similar to that shown in Fig. 3. Consequently, all loads at point 3 will notice the sag. In fact, all loads downstream of point 1 will notice some amount of sag.

Since the majority of faults on overhead distribution systems are temporary (meaning the fault will be cleared if power is interrupted and restored), temporary faults on lateral taps can be cleared by the recloser before the lateral fuse blows. This is usually done with the instantaneous element of the recloser in the substation. This practice is known as "fuse saving."

A disadvantage of fuse saving is that all the customers on the feeder will experience a blink for most lateral faults. This illustrates a tradeoff between power quality (more momentary interruptions) and reliability (fewer fuse operations). Because of the momentary interruptions, many utilities are choosing to operate in a fuse-blowing mode.

Voltage transients

Most surge voltages occurring in low-voltage ac circuits typically originate from lightning and utility system switching. In the US, lightning flash densities approach 10 flashes/km^2/yr in some areas of Florida. Peak currents from lightning strikes can exceed 200 kA with a 10/350 µs duration. Current rise times as fast as 0.1 to 100 µs can occur. Multipulse surges are experienced in over 70% of direct strike situations.

This is a naturally occurring phenomenon where up to 20 restrikes may follow the path of the main discharge at intervals of 10-200 milliseconds. Peak currents of 200-500A lasting 1-2 seconds may also occur. Obviously with the high number of sensitive electronic equipment in use today, the potential for lightning damage is significant. Telecommunications radio sites are particularly vulnerable to the effects of lightning and overvoltage transients because of their often-elevated location.

Besides lightning surges, isolated stations at the end of long distribution lines are also prone to equipment damage. This is due to temporary overvoltages caused by switching surges or poor power supply regulation. Utility capacitor banks have long been an accepted design practice deemed necessary for efficient voltage regulation on transmission lines and distribution feeders. Switching capacitors, either in one block or in steps, is also part of a normal day's operation. This is because heavier loads require higher compensation. A downside of these capacitor switching events is the associated voltage transients or surges. Typical levels of switching transients range from 1.2 to 4 times the nominal.

Although these low frequency transients are generally not a problem for utility equipment, they can cause problems for low voltage power electronic-based loads. An example is adjustable speed drives, which are susceptible to dc link overvoltage trips. Transients can get worse if the customer has power factor correcting capacitors. The reason is the transient magnification due to resonance.

Using pre-insertion devices, such as pre-insertion resistors or reactors, can control the energizing transient. In this method, the additional series impedance helps in damping out the first peak of the transient, which is always the most damaging. Applying phase angle control techniques, known as synchronous closing, can also control switching transients. This method relies on performing the switching operation when the voltage across the switch is equal to zero. When capacitors are switched at zero-crossings, it creates minimal transients. A typical connection time of a pre-insertion device is a half power frequency cycle. Any of these transient control devices add to a significant increase in cost.

Harmonics

In an ideal power system, the voltage supplied to customer equipment, and the resulting load current, are perfect sine waves. In practice, however, conditions are never ideal, so these waveforms are often distorted. This deviation from perfect sinusoids is usually expressed in terms of harmonic distortion of the voltage and current waveforms. Nonlinear loads, such as ac and dc adjustable speed drives, power rectifiers and inverters, arc furnaces and discharge lighting (metal halide, fluorescent, etc.), and even transformers, may

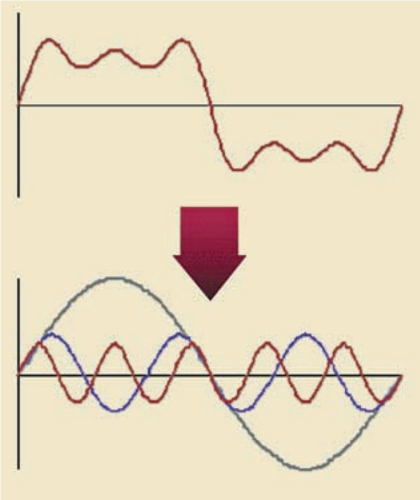

Fig. 4 Distorted Wave Composed by the Superposition of a 60 Hz Fundamental and Smaller Third Harmonic and Fifth Harmonics.

generate enough harmonics to cause distorted waveshapes.

Figure 4 shows how a distorted wave can be broken into its harmonic components, by a method called Fourier analysis. In this figure, the distorted wave is composed of the fundamental wave combined with wave 3rd and 5th harmonic components.

The deleterious effects of harmonics are many. A significant impact is equipment overheating. Overheating invariably leads to shortened equipment life. Harmonics can also create resonance conditions with power factor correction capacitors, resulting in higher than normal currents and voltages. This can lead to improper operation of protective devices, such as relays and fuses.

Remedies

If you have ever shopped for a surge suppressor, you are aware of the transient overvoltage condition that can develop in your electric power supply during thunderstorms. Many loads, including much of the high-tech industry, require uninterrupted service with voltages within a narrow band. At present, many small, medium and large-scale protection solutions are available for different applications - from alternative products to point-of-application. The debate continues in the industry about whether it is more cost-effective to protect end-user equipment at the point-of-use, at a branch circuit, or at a facility level. Based on this, the power quality, protection equipment market boasts a plethora of field-tested devices, the most common of which are:

Transient voltage surge suppressors (TVSSs),
Line conditioners, active filters,
Uninterruptible power supplies (UPS),
Motor generator sets, and
Ferroresonant transformers.

According to recent strategic research by Frost & Sullivan, the US power quality, protection product market had revenues of $2.1 billion in 1996 and is expected to reach $8.37 billion in 2003.

Riding through voltage sags

The remedies for sag include solutions that allow the equipment to "ride through" a majority of sag conditions. The cost depends on the level of protection desired with the highest being at the facility level and the lowest at the equipment level. Most protection equipment for sag falls under the general category of "power line conditioners (PLC)." Typical PLC equipment includes such devices as uninterruptible power supplies (UPS), motor generator sets, ferroresonant transformers, and magnetic synthesizers.

Uninterruptible power supply (UPS) devices provide power to critical loads at all times. The two classifications of UPS systems are "rotary" and "static." A rotary UPS uses some form of a motor generator to provide uninterruptible power, while a static UPS has no moving parts and typically uses power semiconductors.

A static UPS system consists of a rectifier/charger, a battery bank, a static inverter and an automatic transfer switch. A utility line-feed powers the on-line UPS. The rectifier converts the ac power to dc. The battery bank can be charged by the rectified dc power. The inverter is fed from either the rectifier or the battery. At the output of the inverter is the conditioned ac power that serves the sensitive electronic equipment. Because of the double-conversion (ac to dc, then dc to ac), variations in the input frequency have little effect on the output. An on-line UPS typically has a solid-state transfer switch for switching directly to utility power if an internal element fails within the UPS.

An alternative to the on-line UPS is the standby power supply (SPS) alternatively called an offline UPS. This device switches to a battery supply upon loss of utility power. The SPS is effective only when the equipment being protected can withstand the transfer time, usually a few milliseconds. When voltage is normal, the transfer switch returns to the normal utility feed.

Motor generators consist of an electric motor driving a generator. They convert incoming electrical energy into mechanical energy and back again into electrical energy. The mechanical shaft isolates the electrical load from incoming disturbances such as voltage impulses, surges and sags. The motor generator rides through many short "momentary interruptions" but will not protect against sustained outages. The principle function of engine generator sets is to provide emergency power to critical loads for extended periods of time. The complexity of an engine generator system is directly proportional to its size. Continuous power engine generator sets are available in sizes ranging from a few kilowatts to many megawatts depending on the load served. Combining an engine generator system with an uninterruptible power supply is becoming a highly regarded method of assuring continuous power within a facility.

Ferroresonant transformers are also becoming popular in many applications. Also known as constant voltage transformers (CVT), these devices depend on the property of a transformer design to maintain the output voltage within a desired limit despite wide fluctuations in the input. A CVT is basically a 1:1 transformer operated high in the saturation curve for the transformer. The output contains a parallel resonant tank circuit and draws power from the primary to replace power delivered to the load. This allows the output voltage to be less affected by a change on the input voltage. CVTs respond best to slow changes in voltage.

A device that is used to protect larger loads is the magnetic synthesizer. Used for "ride through" capability for large computers and other sensitive loads, the magnetic synthesizer is an electromagnetic device that takes incoming power and regenerates a clean, three-phase ac output waveform regardless of input power quality. The output waveform is built by combining distinct voltage pulses from saturated transformers. The waveform energy is stored in the saturated transformers and capacitors as current and voltage. This energy storage enables the creation of a clean waveform with little harmonic distortion.

Limiting voltage surges

ANSI Standard C62.41 identifies

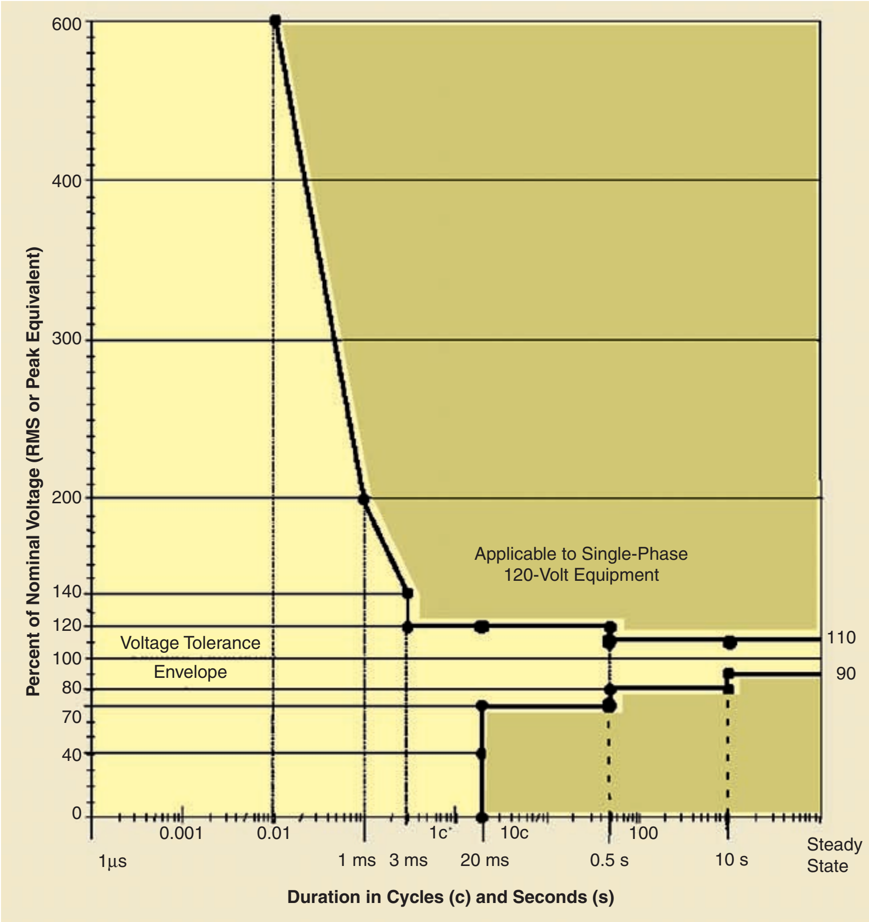

Fig. 5 ITIC Curve showing voltage tolerance of electronic equipment

two distinctive forms of lightning protection, i.e., one designed to protect the building structure and fabric and a second to protect sensitive equipment inside the building. This standard discusses methods to determine the maximum voltage surge that is likely to travel along a line and, hence, the maximum one that a surge protection device (SPD) must divert successfully to protect the equipment connected to the ac line. The largest surge that is likely to appear on the busbars of the main power distribution board for a building is 6 kV and 3 kA. Hence, an SPD fitted to the board must be able to divert, safely, a surge of this magnitude.

When selecting components for use in a SPD, designers choose between high current handling capability and high-speed operation. Some possible components are strong in one of these parameters and others in the other. Lightning induced voltage surges can rise from zero to up to 6kV in about 1 (s. Surge diverting components must therefore operate quickly. Fuses and circuit breakers do not provide protection, as they simply cannot work quickly enough.

Voltage-limiting components used in modern SPDs are usually selected from three main types:

1) Gas discharge tubes (GDTs),

2) Metal oxide varistors (MOVs) and

3) High-speed clamping diodes.

Gas discharge tubes can handle very high surge currents, but are relatively slow to start and can thus let through a lot of the surge before they operate. Metal oxide varistors can handle fairly high surge currents, but their clamping voltage rises as more surge current passes through them. High-speed suppression diodes can only handle relatively small surge currents, but they do have very accurate and rapid voltage clamping performance.

At present, most manufacturers are using the metal oxide varistor or MOV in producing the transient voltage surge suppressor (TVSS). The TVSS technology includes four types of products based on application - receptacle, individual equipment, residential, and electrical distribution/service entrance types. TVSSs can be either hard-wired into the equipment that is to be protected or applied as a separate component. The latter type, called point-of-use TVSS, includes line cords and plug-ins. In choosing a plug-in TVSS, one should look for UL 1449 listing, proper energy and clamping voltage specifications that match the requirements, and the response time.

Over- & under-voltage coverage

Long duration over voltage and under voltage are voltage regulation problems that are partially solved by utilities through better planning of the distribution system. Choices are choosing the proper sizes of transformers and line conductors and adding capacitors and voltage regulators at various points. It is the responsibility of the customer to protect the more sensitive loads that require a better voltage regulation to operate properly.

Protection from harmonics

There are many ways to reduce harmonics, ranging from variable frequency drive designs to the addition of auxiliary equipment. The most common, and perhaps the least expensive solution, is to accommodate harmonic currents rather than attempt to eliminate them. By utilizing more copper in the power distribution system in the form of "K-Factor transformers" (or transformer derating) and individual neutrals on branch circuits, the overloading and heating effects of harmonics can be minimized. On three-phase circuits the neutral conductor should be 1.7 times the size of the phase conductor. The reason, as mentioned before, is the presence of triple harmonics in the neutral.

Alternately, pesky harmonics can be mitigated with passive and active filters. Passive filters, consisting of tuned series L-C circuits, are the most popular. However, they require careful application, and may produce unwanted side effects, particularly in the presence of power factor correction capacitors.

The active filter concept uses power electronics to produce harmonic components that cancel the harmonic components from the nonlinear loads so that the current being supplied from the source is sinusoidal. These filters are costly and relatively new and a number of different topologies are being proposed. A common active filter configuration is based on a pulse-width modulated (PWM) voltage source inverter that interfaces to the system through a filter. In this configuration,

Box A

Causes of poor PQ

Voltage sag (dip): A decrease between 10% and 90% in rms voltage or current at the power frequency for duration from 0.5 cycles to 1 min.

Voltage swell (surge): An increase to between 110% and 180% in the rms voltage or current at the power frequency for durations from 0.5 cycles to 1 min.

Overvoltage: An increase in the rms ac voltage greater than 110 % at the power frequency for duration longer than 1 min.

Undervoltage: A decrease in the rms ac voltage to less than 90 percent at the power frequency for a duration longer than 1 minute

Interruption: Momentary power interruptions of duration - 1/2 second to greater than 1 minute.

Impulsive transient: A sudden and short duration disturbance by a very rapid change in the steady-state condition of voltage, current, or both, that is unidirectional in polarity. Frequency Range: >5 kHz (High Frequency); Duration: 30-200 (sec.

Oscillatory transient: A temporary rapid fluctuation in the steady-state condition of voltage, current, or both, that includes positive and negative polarity values. Frequency range: 500 Hz - 2 kHz. Duration from 0.5 cycles - 30 cycles.

Harmonics: Currents produced by nonlinear devices at harmonic (integer multiple of the fundamental frequency) frequencies injected into the system.

Notching: Periodic voltage disturbance caused by the normal operation of power electronics devices when current is commutated from one phase to another.

Noise: Any unwanted electrical signals with broadband spectral content lower than 200 kHz superimposed upon the power system voltage or current in phase conductors, or found on neutral conductors or signal lines.

Voltage fluctuation (flicker): Continuous, rapid variations in the load current.

Frequency variation: The deviation of the power system fundamental frequency from its specified nominal value (e.g., 50 or 60 Hz).

Outside the home

Outside the homes and offices, power electronic devices play a major role in the manufacturing industry. Often, large electric power drives are engaged in activities ranging from small-scale milling to energy-intensive smelting. The US Department of Energy estimates that between 1991 and 1994, the manufacturing sector increased its use of net electricity by 12 percent. This increase was mainly in two industries: the chemical (17% increase) and petroleum refining industries (13%). Leading the 17% growth in the chemical industry was an increase in the use of machine drives. Net electricity for machine drives increased by nine percent. The petroleum refining industry displayed similar results. Leading the 13-percent growth in net electricity consumption in this industry was a 9-percent growth in using electricity for its machine drives.—*BC*

the active filter is connected in parallel with the load being compensated. Reduction in the harmonic voltage distortion occurs because the harmonic currents flowing through the source impedance are reduced. The desired current waveform is obtained by accurately controlling the switching of the insulated gate bipolar transistors (IGBTs) in the inverter.

Premium power

Premium power refers to a service that inherently would be more reliable and devoid of many of the common power quality problems discussed so far. Although such a condition is hard to achieve for power supplied from a utility, new power electronic devices are just entering the market that might enable utilities to guarantee pure and reliable power to customers. In 1992, the concept of the custom power park, also known today as the Premium Power Park (PPP), was introduced by Westinghouse (now Siemens) in order to meet customer needs. According to this concept, the tenants of an industrial or commercial office park would be provided with a guaranteed level of electrical service quality made possible by new custom power devices. Some of the more mature technologies behind the PPP concept are listed here:

• Distribution Static Compensator (D-STATCOM): This is a solid-state dc to ac switching power converter that consists of a three-phase, voltage-source inverter. In its basic form, the D-STATCOM injects a voltage in phase with the system voltage, thus providing voltage support and regulation of reactive power flow. Because the device generates a synchronous waveform, it is capable of generating continuously variable reactive or capacitive shunt compensation up to its rating.

• Dynamic Voltage Restorer (DVR): The DVR is a solid-state dc to ac switching power converter that injects a set of three single-phase ac output voltages in series with the distribution feeder and in synchronism with the voltages of the distribution system. By injecting voltages of controllable amplitude, phase angle and frequency (harmonic) into the distribution feeder in instantaneous real time, the DVR can "restore" the quality of voltage at its load-side terminals when the quality of the source-side terminal voltage is significantly out of specification for sensitive load equipment.

• Solid-State Breaker (SSB): This device consists of two parallel-connected circuit branches: a solid-state switch composed of gate turn-off thyristors (GTOs) and a solid-state switch using silicon-controlled rectifiers in series with a current limiting reactor or resistor. The GTO switch is the main circuit breaker used to clear source-side faults in less than 1/2 cycle. It is normally closed and conducts current uninhibited until the magnitude of the current reaches a pre-set level at which point it opens rapidly interrupting the current flow.

• Solid-State Transfer Switch (SSTS): The SSTS consists of two three-phase SSB's, each with independent control. The status of the three individual phase switches in each SSB is individually monitored, evaluated, and reported by continuous real-time switch control and protections circuits. The operation of the two SSB's is coordinated by the transfer switch control circuit that monitors the line conditions of the normal and alternate power sources and initiates the load transfer in less than 1/4 cycle.

Conclusions

With a restructuring industry finding

it harder and harder to maintain the reliability and quality of service, high power quality will continue to be a challenging attribute to attain. Additionally, open competitive retail access to customers by utility companies and energy service providers also means that they are going to be held accountable for the level of power quality and reliability delivered. Maintaining cordial customer relationships that include fast response to trouble calls, troubleshooting customer complaints, and foolproof remedies for problems, could become a high priority.

The challenges in power quality are also spawning a market for new technological innovations in equipment that guarantees safe and reliable power delivery. Custom power devices, as mentioned in this article, are but some of many new innovations entering the market. New generation technologies centered on distributed generation (DG) are now becoming feasible. Distributed generation technologies offer a wide variety of business opportunities to the electric power industry. Several levels of improvement are possible, depending on the DG equipment used and its placement on the system. The most basic installation is a backup generator with automatic startup. It can eliminate long-duration customer interruptions. Photovoltaics, fuel cells, microturbines, and/or energy storage can also be employed with a UPS. However, because these generators typically require 5 to 10 seconds to get them on-line following a disturbance, they cannot be relied on to eliminate unexpected voltage sags or momentary interruptions.

Often, adhering to recommended practices and applying plain common sense can make the difference. It has been stated that improper wiring and grounding is the cause of 80% of all power quality problems. Proper wiring includes choosing the right conductor sizes, particularly when a high percentage of harmonic loads are present. Triplen harmonics, or the odd multiples of the third harmonic, add in the neutrals of three-phase, four-wire systems. Sometimes, currents in the neutral conductor can approach 170% of those in the phase conductors. Therefore, in situations, where the neutral has to be shared between branch circuits, the neutral conductor should be of the appropriate size so as not to cause overheating.

Improperly installed grounds can result in ground current loops that affect data communications. It can also result in dangerous "touch" potentials for equipment operators. Computers use the ground as a zero reference and currents in the ground circuit will interfere with the computer's circuitry. When it comes to grounding practices, one should follow the National Electrical Code to the letter to be on the safe side.

Read more about it

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Badrul H. Chowdhury obtained his B.S degree in Electrical Engineering from Bangladesh University of Engineering & Technology, Dhaka, Bangladesh in 1981. He obtained his M.S. and Ph.D. degrees also in Electrical Engineering from Virginia Tech, Blacksburg, VA in 1983 and 1987, respectively.

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