LIVE SOUND INTERNATIONAL

AUGUST 2005

Protection Or Quality Or Both?

When talking power, it is vital to know the differences

By Dennis Ver Mulm and Victor Pavona

The topic of AC power protection has become somewhat one-dimensional for many who regularly work with sound systems, because the concept of a power problem is tied to a specific unpleasant memory of a power disturbance that caused a great deal of grief, and perhaps a small fortune in recovery costs.

This explains why some are convinced that power protection is all about guarding against power outages or regulating voltage, while others obsess about power line noise or prevention of voltage surges and transients. It's not uncommon to find surge protectors, voltage regulators, and noise filters all labeled as "power conditioners."

We see a lot of discussion about the need to protect systems from power problems, but there's little discussion about the nature of power disturbances themselves. This is unfortunate in an industry where so much depends on digital electronics that must perform reliably and produce the highest quality sound.

Because microprocessors and other sensitive circuitry are a critical part of almost every system, it's important to think differently about the interplay between the electronic equipment and the electricity that powers it.

A good place to start is by understanding some basics. There are four ways in which modern A/V systems can be affected by power quality anomalies, and these can be called "The Four D's."

SINGLE OCCURENCE

The first D is *destruction*. So much energy is involved with a power problem that a single occurrence results in the immediate destruction of an integrated circuit or transistor. We typically refer to these events as voltage surges, impulses, or high-energy transients, and they're usually associated with lightning.

However, there are other causes. Voltage surges can be caused by large industrial loads turning on and off, a windstorm blowing power lines together, or even something more mundane like the aging ballast of a fluorescent lighting fixture.

Whatever the source, the destructive power disturbance overwhelms the electronic device and leaves smoke, charring, and visible damage in its path.

The second D is *degradation.* The energy level of degrading power disturbances is insufficient to destroy an integrated circuit immediately. Rather, slowly degrading disturbances erode internal semiconductor material, much like rust eats away at unprotected metal. Thus damage is slow, cumulative, and invisible.

Eventually, the semiconductor device breaks down internally, and unfortunately, when failure does finally occur, it's often difficult to establish cause and effect.

The third D is *disruption.* Any system with a microprocessor is subject to disruptive power disturbances. These disturbances contain the least amount of energy but are far more mischievous because disruptive disturbances have two power pathways to gain access to a system.

The first pathway, between the hot and neutral conductor of the electrical system, is called the normal mode pathway. When high frequency, low voltage, normal mode power disturbances are present, they may easily couple through the power supply or enter a system via numerous parasitic pathways. Often mimicking legitimate level signals, they can still cause microprocessor lockups, errors, or other unexplainable operational problems.

The second pathway for disruptive disturbances is between the neutral and the ground conductor of the electrical system, called the common mode pathway. This path is particularly problematic for computer-based components that are equipped with three-conductor grounded power cords.

Common mode power disturbances can easily upset a microprocessor's voltage reference, causing logic errors and a similar pattern of lockups and unwanted reliability problems. And they're almost always associated with system disruption.

The fourth D is *dynamics.* It's not as harmful as the first three, but does prevent a system from attaining its highest possible dynamic range. Some power conditioning approaches help with this, but it's equally important not to overlook simpler things like making sure that electrical circuits are properly wired and grounded

Insuring that circuits have enough "ampacity" (available amps) to provide for the needs of the load – without distorting or sagging circuit voltage – is also critical.

Let's take a look at the various types of power quality disturbances and the type of power protection device that can be used to solve each one.

Surge Diverter. The most commonly recognized power protection device. Often called a TVSS or transient voltage surge suppressor, the term surge diverter is a more accurate term because it describes how the device functions.

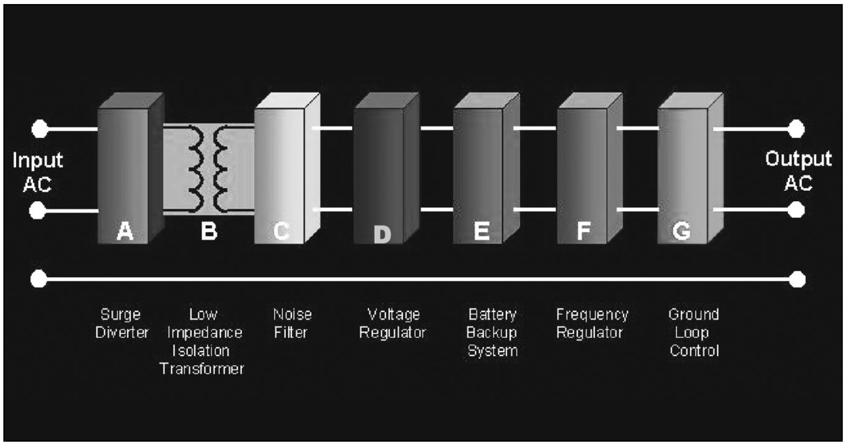
Surge diverters are usually components like metal oxide varistors, silicon avalanche diodes, or gas discharge tubes. Each of these devices performs differently with respect to clamping voltage and response times, and all have different energy handling characteristics. Some exhibit performance deterioration in the face of repeated high-energy surges.

As a result, many manufacturers of surge diverter-based devices have focused on these technical performance issues as a way of competitively differentiating their products.

The bits and bytes of performance specifications, however, are not the most important issue to understand. These devices function by diverting surge energy from one power conductor to another.

This means that when a potentially destructive normal mode surge occurs, the surge diverter shunts most of it to the safety ground conductor of the electrical system. It isn't much of a problem if the protected load is a simple electrical device, but if the load is microprocessor based, it can be a big problem.

It's not unusual to install a surge diverter to prevent power supply failures and to have processor lockups, data errors, or other "soft" system failures begin to occur. This is because the surge diverter has converted a normal mode disturbance into a common mode one. Hardware damage has been prevented but a system failure of some type still results. Therefore, surge diverters are useful in addressing the first D – destruction.



The "ABCs" of power conditioning

Isolation Transformer. Sometimes a misunderstood technology. A true isolation transformer will have two windings, one primary and one secondary. The primary winding is connected to the electrical system and couples power via an electromagnetic field to the secondary winding, which powers the electronic load. There are two main benefits to using a true isolation transformer.

First, no direct electrical connection exists between the electronic load and the electrical system. Isolation transformers often have at least one Faraday Shield between the windings, which acts to increase the inter-winding capacitance slightly and to function as a path to ground for noise currents. This allows the transformer to act as a buffer against low-voltage, high frequency disturbances.

A second benefit of the isolation transformer is that the National Electrical Code (NEC) allows the output neutral conductor to be re-bonded to the safety ground conductor. This simple action eliminates neutral-to-ground voltages that exist in the branch circuit wiring.

It also permits surge diverters and noise filters, when connected across the transformer secondary, to function without creating a neutral to ground disturbance. Isolation transformers create a very friendly electrical environment for microprocessor-based systems.

Regardless of the power aspect being addressed, it takes quality components to get the job done correctly.

A second configuration for isolation transformers is gaining recognition. This configuration is referred to as balanced power, where the transformer secondary does not have its output neutral bonded to ground. Instead, the secondary winding is center-tapped with the center tap acting as the ground for the connected load.

The phase and neutral conductors of the secondary (while still maintaining a full voltage potential between them) each measure 50 percent of the source voltage to the center tapped ground. Balanced power technology assumes that electrical noise at any frequency will be imposed in equal amplitude but exactly opposite phase across each half of the center-tapped transformer secondary. Full cancellation of any noise currents is assumed to occur under such circumstances.

There is some debate over the effectiveness of balanced power configurations, but it is reasonable to assume that, when correctly designed and constructed, balanced power can reduce electrical noise at least as efficiently as other technologies. Balanced power transformers do not offer a quiet neutral to ground reference required for computer systems to operate reliably since bonding of neutral to ground is not permitted with balanced power configurations.

Isolation transformers are viewed negatively by some in the audio industry because of a perception that they alter sound characteristics. This is true for isolation transformers with high impedance characteristics.

When a sudden change in load current occurs (as can happen with higher powered sound systems) a high impedance isolation transformer cannot rapidly transfer current from primary to secondary. This starves the load for current, distorts the secondary voltage waveform and sound reproduction suffers.

It's important to note, however, that newer isolation transformer technology is available that is low impedance in nature. One common design of low impedance isolation transformer provides a steady state run current of 12 amps with the ability to supply up to 192 amps for 1 second without any accompanying voltage distortion appearing on the transformer secondary. Low impedance transformer designs are acoustically quiet and completely compatible with audio and video systems.

Power Line Noise Filter. Surge diverters clamp transient voltage disturbances at around 250 volts to 300 volts but do nothing to prevent power disturbances of lower amplitudes from reaching the electronic load. Surge diverters also prevent destruction, but they do little to prevent degradation of electronic components. This is the job of the noise filter.

Filters address lower amplitude power disturbances, and they also function by diverting these disturbances to ground. Filters are excellent at preventing degrading power disturbances but because they function like surge diverters, they also create potentially disruptive disturbances by converting normal mode to common mode.

Filters are constructed of inductors and capacitors and are tuned to offer a low impedance path to ground for a specific range of power disturbance frequencies. A negative aspect of noise filters is that the impedance of the filter combines with the impedance of the branch electrical circuit, which often results in a shift in the frequency response of the filter.

Gain in noise amplitude at certain frequencies is frequently observed. As a result, filters work best when they are individually tuned to the unique impedance characteristics of each application.

Installing a surge diverter and a filter on the secondary of a low impedance isolation transformer offers the best of both worlds. The filter may be designed around the fixed impedance of the transformer secondary so that its performance is the same regardless of where it is installed. The surge diverter handles the large amplitude transients and the filter addresses what slips by the surge diverter.

Also, if the transformer has a neutral to ground bond, the filter and surge diverter can do their jobs without creating a neutral to ground disturbance that might be disruptive for a microprocessor based system.

Voltage Regulator. Intended to stabilize the voltage that powers an electronic system. A variety of devices can function as a voltage regulator. These include ferro-resonant transformers, buck/boost autoformers, tap switching autoformers, and tap-switching isolation transformers. Unfortunately, voltage regulators are frequently misapplied for two primary reasons.

Voltage regulation is seldom necessary when the electronic system uses a power supply design that is tolerant of supply voltage variations. Many modern systems are powered by switch mode power supplies (SMPS), which "gulp" power from the power line in a discontinuous fashion.

SMPS are constant power devices. In other words, when line voltage decreases, the current gulp gets bigger. When line voltage increases, the current gulp gets smaller. Either way, power consumed (volts times amps) stays the same.

SMPS technology is largely immune to voltage regulation issues provided the branch electrical circuit has adequate ampacity, which leads to the second reason why voltage regulators are misapplied.

The job of a voltage regulator is to address both over voltages and under voltages. While we perceive that the voltage regulator is stabilizing voltage, it's actually accomplishing that task by regulating current flow in the electrical circuit. While it's relatively easy for a regulator to reduce over voltage, an under voltage condition is something else entirely – especially if the under voltage is the result of an overloaded branch circuit, distribution panel, or service transformer.

To mitigate an under voltage, the voltage regulator must get extra current from somewhere. If the under voltage condition exists because of ampacity problems in the branch circuit or facility electrical distribution, a voltage regulator will provide little benefit and may actually worsen circumstances by adding additional load to the circuit. Always remember that a voltage regulator is not some type of electrical "perpetual motion machine."

Voltage regulators should be used selectively for those loads with linear style power supplies that are adversely affected by voltage variations in the primary utility power supply. If a low voltage condition exists because of overloaded branch circuits, distribution panels, or service transformers, the underlying ampacity problem must first be addressed before a determination can be made that a voltage regulator is necessary.

Battery Backup. Electrical and electronic systems can't function without electrical power. Battery backup systems or uninterruptible power supplies (UPS) are devices that store energy in chemical form (storage batteries).

When commercial power is lost, the chemical energy is transformed into DC electrical current, which is provided by the battery to an electronic circuit called an inverter. The inverter changes DC power into AC power for use by the electronic system. In their simplest form, UPS products are devices for ensuring continuity of power when utility power is lost. But note that they ARE NOT automatically power quality solutions.

UPS designs vary greatly. Some have "standby" designs, meaning they only begin converting DC to AC a few milliseconds after commercial power has been lost. Others have "on-line designs" which constantly take incoming AC power, convert it to DC (some of which is used to trickle charge a storage battery), and then reconvert it to AC power for the load – a technique often called "double conversion."

When commercial power is lost, the storage battery then becomes the primary DC power source for the inverter, which continues to provide AC power for the load without the milliseconds delay that characterizes standby designs.

There has been much discussion over the relative power conditioning abilities of each design, with on-line UPS products being touted as better power conditioners because of their double conversion technique. However, when surge diverters, noise filters and low impedance isolation transformers are combined with either design, there is little noticeable difference in the power conditioning capability. One area where on-line technology is superior is in its ability to smoothly regulate line voltage, which is a side benefit of the double conversion process.

More importantly, when evaluating UPS technology, it's critical to know some specifics about the type of voltage waveform the UPS provides to the electronic load. The power provided by the electric utility is low distortion and has a sinusoidal wave shape. This is the type of power on which electronic systems have been designed to operate.

It's not uncommon to find UPS systems with inverters that create non-sinusoidal (square wave or modified square wave) waveforms. These designs often exhibit incorrect output voltages, are high in harmonic distortion, contain significant voltage transients and noise, and are generally unsuitable for use with sensitive electronic systems when ultimate reliability and performance are important goals. So exercise care when evaluating and selecting UPS technology.

Frequency Regulator. AC power in North America is generated at a frequency of 60 Hz (60 cycles per second, while in Europe and much of the rest of the world, AC power is generated at 50 Hz.

In most developed countries, frequency regulation is not required since electric utilities generate power that is frequency stable. This is not necessarily true for developing or emerging countries. Where frequency regulation is required, a good solution is the inverter of an on-line UPS, which tightly regulates frequency as a by-product of its double conversion operation.

Ground Conditioning. Different components of an interconnected system are frequently not all at the same chassis potential with reference to ground. The result is a ground loop, which becomes a convenient path through which equalization current begins to flow (60 Hz. equalization currents are the most recognizable since an audible hum is the usual symptom).

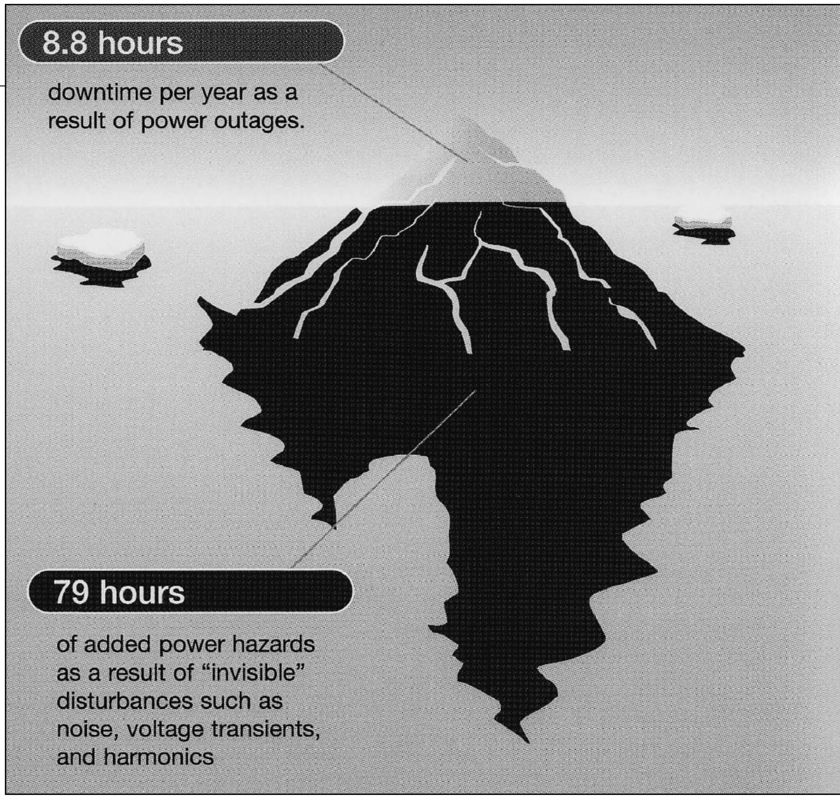
But ground loops exist at other frequencies as well, some of them high enough to alter or interfere with data communications when the ground loop occurs in the shield of data, signal or communication cables. One method for addressing them is to power all system components from a commonly grounded source.

Another is interconnecting components with fiber optics or employing opto-isolators. New technology also exists where a specially designed inductor is placed in series in the safety ground conductor of the electrical supply to prevent high frequency noise from gaining entry to a system's communication, data, and signal cabling. This technique is known as ground conditioning.

ALREADY RELIABLE, BUT...

In a recent study, the Electric Power Research institute (EPRI) discovered that the average, well managed electrical supply system in North America experiences about 8.8 hours of power outages annually, which translates to a reliability rating of about 99.9 percent.

This research goes on to state that when all other power disturbances are factored in, the average reliability level drops to 99 percent, or approximately 79 more hours per year in which the quality of electrical power is not satisfactory for the needs of electronic systems. Like an iceberg, the power disturbances we don't see are the ones that are truly problematic.



Power problems that we can easily see, such as outages, are only the tip of the iceberg.

Earlier we looked at how much the audio industry depends on its electronic systems to function reliably, with no failures, and at the highest level of performance. Therefore, it's vital to stop thinking one-dimensionally about *power protection* and to start thinking comprehensively about the issue of *power quality.*

Only when we start with the ABCs and consider all four Ds when formulating any power solution can we begin to master our electronic tools – not be their victim. ■

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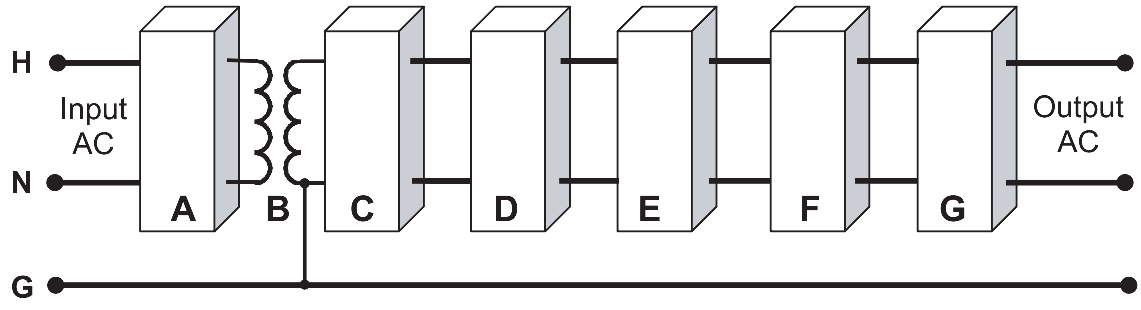
ETA Systems - The ABC's of POWER Conditioning®



A The Surge Diverter

This is the most commonly used "solution" because it is the least expensive and best-recognized power protection device. Surge diverters can only protect from transient voltages that exceed about 250 volts. When these large voltages occur, surge diverters clip the excess voltage and send it to ground where it is converted into a common mode power disturbance that can disrupt microprocessor function. Because transient voltages smaller than 250 volts slip by the surge diverter, the electronic system may be exposed to substantial degrading energy.

B The Low Impedance Isolation Transformer

The low impedance isolation transformer provides an inductive cushion for the load and enhances the operation of surge diverters and noise filters by re-establishing a vital neutral to ground bond permitted by National Electrical Code. The bond prevents the formation of common mode voltages created when surge diverters and noise filters shunt power disturbances to safety ground.

C The Power Line Filter

Power line noise filters address the low amplitude, high frequency noise disturbances that are missed by the surge diverter. Quality noise filters are often left out of many power protection devices. Like surge diverters, they operate by shunting noise to safety ground.

D The Voltage Regulator

Voltage regulators are responsible for keeping power line voltage within specified upper and lower limits. Many systems use switch mode power supplies (SMPS) which do not require tightly regulated voltage. This is fortunate since most voltage regulation technology is obsolete, generates noise, and is unsuitable for use with today's systems.

E The Battery Backup

Computer systems can't function if there is an interruption to their supply of electrical power. In the event of a power outage, the battery backup converts reserve DC energy (stored in batteries) into AC power for the electronic load. The most common type of battery backup is the standby UPS, which switches to batteries when power is lost. More expensive on-line UPS systems are also available to provide constant AC to DC to AC power conversion. Many on-line systems can also regulate voltage. Few UPS systems, regardless of the design, provide good common mode protection because they do not include an output isolation transformer.

F The Frequency Regulator

Frequency regulators ensure that the power line frequency stays at a constant 60 Hz. (50 Hz. in Europe and much of the rest of the world). In most well-developed countries, frequency regulation is not required since the power utility provides very frequency stable electrical power. This is not always true in developing countries or when operating on generator power. When frequency regulation is required, an on-line UPS or inverter is the best way of providing frequency stable AC power.

G Ground Loop Control

When electronic systems are connected together throughout a building, the natural variations in electrical ground impedance cause noise currents to flow in the loops created by the grounding conductors of data and signal cables. Low frequency ground loop currents may cause audible hum while high frequency loop currents may alter data, cause communication errors or system reliability issues.

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