Protection From Incoming Power Line Voltage Anomalies

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Destructive Effects of Anomalies

Power line voltage anomalies are the greatest source of destructive and disruptive phenomena that electrical and electronic equipment experience in day-to-day operations. The causes may vary significantly with location, but the results are the same—either the equipment will fail immediately or degrade over a period of time. Degradation may appear as reduced Mean Time Before Failure (MTBF), or as some form of momentary or long-term downtime.

These anomalous events can result in a need for replacement, repair, reprogramming, or rerun of the program in progress. Any of these events can result in lost time and money. All of these events can be totally eliminated with the appropriate power conditioning equipment, properly installed and maintained. Most of these events can be eliminated through the correct use of relatively inexpensive protection equipment.

This paper examines the sources and effects of line voltage anomalies, and the characteristics and merits of the different types of protection available.

Sources of Anomalies

There are four basic sources of anomalies: lightning, the local utility, your neighbors, and your own equipment. Each of these creates its own form of anomaly. A fifth possibility is that related to Murphy's Law—the unexpected, the unusual or the “impossible." An example of the latter category which has occurred more than once is when an automobile struck a utility pole with a 220 kV overbuild line over a 4,160 kV line feeding the local customers. The 220 kV line was shorted to the 4,160 kV line momentarily. This resulted in very high voltages and energy being fed to those customers.

Of the four basic sources, lightning is obviously the greatest normal threat in terms of potential destruction and disruptive phenomena. A direct strike to the power line at the service entrance can create significant damage inside unprotected or improperly protected facilities. The character of an incoming surge will vary significantly with the stroke itself, the actual point of termination, the source configuration of service, and the number of neighbors immediately adjacent to the facility. Table 1 presents the characteristics of a lightning stroke as it terminates on a point. The value range of these characteristics reflects measurements made to date by a number of researchers. Note that the distribution of these values is log-normal, so that although the peak current can achieve 500,000 amperes, the 50th percentile is only 20,000 amperes. Further, since these are the characteristics at the termination point, they are not necessarily those expected at a service entrance.

Table 1: Lightning Stroke Characteristics

Peak Current	2,000 to 500,000 amperes
Rise Time to Peak	50 nanoseconds to 10 microseconds
Energy Transferred	Up to 10^{10} Joules
Surges per Lightning Flash	1 to 26
Frequency Spectrum	1 KHz to 100 MHz

Even under normal conditions, the local utility can create both destructive and disruptive phenomena while living within the standards. Refer to Figures 1, 2, and 3. Figure 1 presents a time-voltage profile of the ANSI (American National Standards Institute) standard that defines the required operating parameters of the local utility.

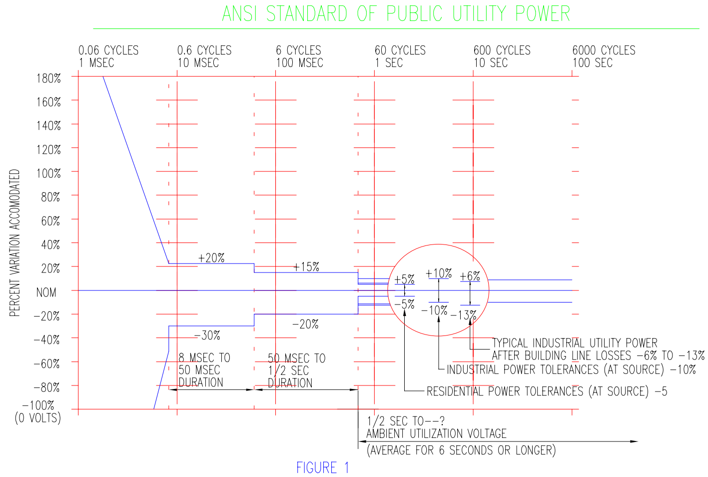


Figure 1: ANSI Standard for Public Utility Power

Figure 2 presents a similar profile that defines the approximate boundaries within which the electronic industry's designs are based.

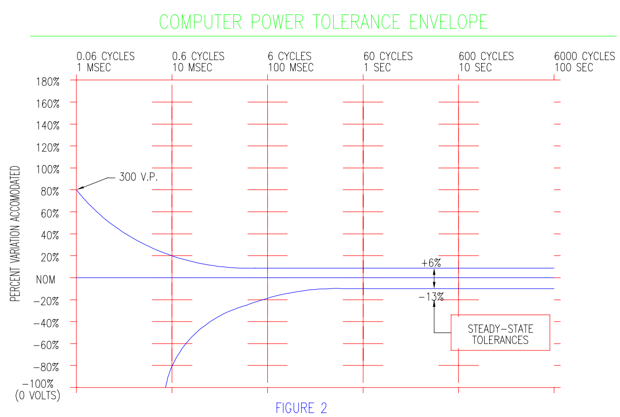


Figure 2: Computer Power Tolerance Envelope

Figure 3 presents the results of superimposing Figures 1 and 2. The conclusion is obvious. Electronic systems are vulnerable to some forms of utility generated transients.

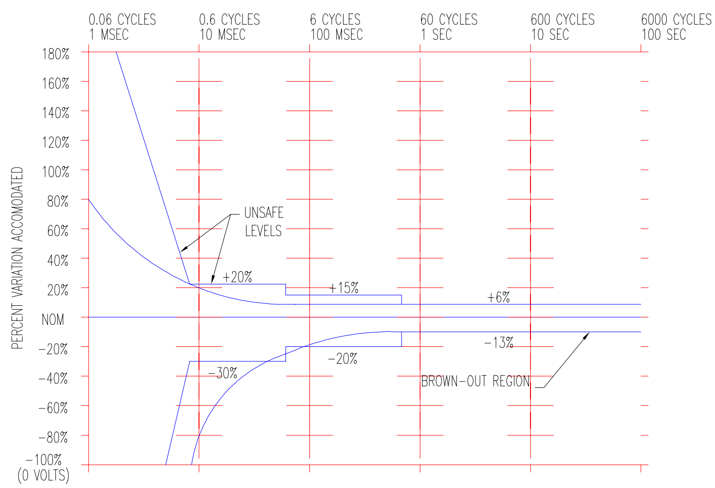


Figure 3: ANSI Standard vs. Computer Tolerance

You and your neighbors add to these problems. Years ago, IBM conducted a now famous study of electrical service anomalies. The study included a very large number of urban sites, very few suburban sites and zero rural sites. The results are summarized by Figure 4. The largest class of anomalies was voltage transients that induced reliability impairment or reduced MTBF.

Reliability impairment can best be illustrated by Figure 5. This figure illustrates the two zones of concern for a protection systems engineer. The actual numbers are not important since they vary between systems to some degree. However, the concept is clear. Both of the two zones must be considered in order to protect the system's MTBF. Voltages rising into the Reliability Impairment zone will reduce the useful life of the system.

In conclusion, a protective system must:

- Prevent instant loss or catastrophic failures.
- Protect system reliability.

ANOMALY	PERCENTAGE	NUMBER PER DAY
OVER–VOLTAGES, INCLUDING SURGES	2%	(6 PER YEAR)
UNDER–VOLTAGES	25%	1
OUTAGES, INCLUDING SINGLE PHASING	1%	(3 PER YEAR)
COMMON MODE TRANSIENTS*	27%	1
TRANSVERSE MODE TRANSIENTS*	45%	2

*49% WERE DAMPED RFI WAVEFORM

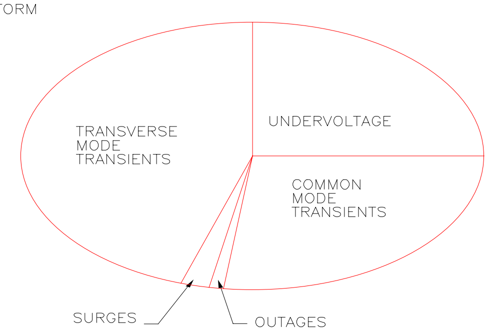


Figure 4: Urban Power Anomalies

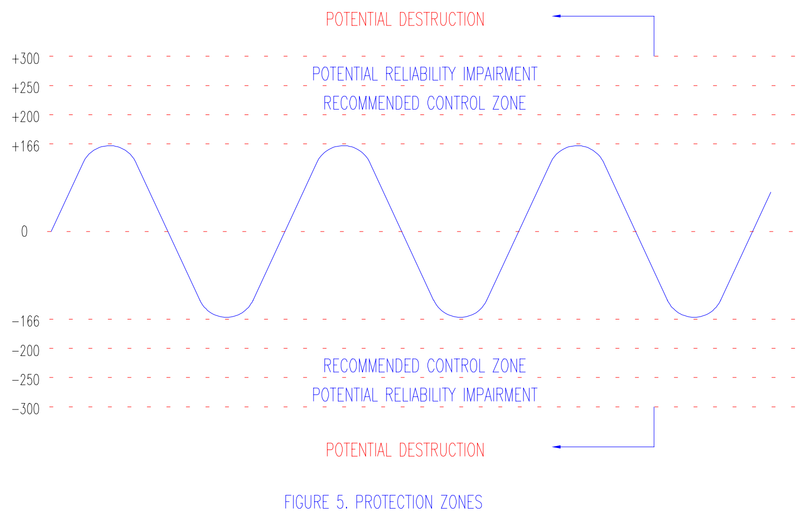


Figure 5: Protection Zones

The Standard for Surge Protection

The IEEE (Institute of Electrical and Electronics Engineers) C62.41-1991 standard was established to define the surge parameters to which electronic equipment is exposed in a field environment, depending on the installation location. This standard was revised in 1991 to more accurately reflect how system exposure depends on the location. For example, an installation in California does not have the same exposure risk as that same installation would have in Florida. The number of lightning days per year in California may be five, whereas in Florida there may be about 100 lightning days per year. In addition to modifying the exposure risk, the category C portion was increased from 6 kV to 20 kV in the 1991 revision.

These waveforms were derived from measurements taken in the field and the laboratory as well as from theoretical calculations. By no means should they be assumed to be the worst-case values, but they do encompass a majority of what is seen in the field. The results are contained in the above mentioned IEEE standard and summarized in Table 2. This defines the test waves that are required to (1) test electronic equipment (i.e., a computer) to confirm whether it fails or not under an impulse condition, and (2) test a surge suppressor to see if it fails or not and take a reading on any let-through voltage.

The test procedure is significant. If a computer is tested once under a Category A impulse, there may not be an immediate failure, but long-term exposure to the day-to-day bombardment is an unknown factor. With in-line surge protection, the unit may not fail immediately. However, if there is a significant amount of let-through voltage, the semi-suppressed waveform may end up damaging the electronics the surge suppresssor is trying to protect.

Table 2: Surge Parameters Per IEEE C62.41-1991

Standard 0.5µs-100 KHz Ring Wave				
Location Category	System Exposure	Voltage (kV)	Current (kA)	Effective Impedance
A1	Low	2	0.07	30
A2	Medium	4	0.13	30
A3	High	6	0.20	30
B1	Low	2	0.17	12
B2	Medium	4	0.33	12
B3	High	6	0.5	12
Standard 1.2/50 µs - 8/20 µs Combination Wave				
Location Category	System Exposure	Voltage (kV)	Current (kA)	Effective Impedance
B1	Low	2	1	2
B2	Medium	4	2	2
B3	High	6	3	2
C1	Low	6	3	2
C2	Medium	10	5	2
C3	High	20	10	2

This paper presents only a small portion of the material found in the IEEE standard. Purchasing a copy and studying it to gain a better understanding of the standard is recommended.

At this time, no pass/fail test program established by ANSI/IEEE has determined the maximum let-through voltage of a Transient Voltage Surge Suppressor (TVSS) product. All that the standard implies is that if the test sample is subjected to the appropriate waveform and the sample does not fail, the unit passes the test. It is important to remember that this standard does not address the reliability impairment problem or let-through voltage.

When testing any product, it is imperative that the proper test be performed. Typically, test engineers think only of a surge existing either hot-to-ground or hot-to-neutral. In reality, a surge can be induced in all four modes: hot-to-neutral, hot-to-ground, neutral-to-ground, and hot-and-neutral-to-ground. For example, if a standard plug-in product is protected with a surge protector providing only hot-to-neutral protection, the device is vulnerable to impulses applied on the other modes. Be aware of which modes are protected when reviewing specifications for plug-in surge protectors.

Standard Categories

The standard separates the impulse tests into three locations, referred to as Categories A, B, and C (see Figure 6). Category C is for service entrance installations. This is for any device installed outside the building, as the power enters the building near the service disconnect, or for runs between the meter and distribution panel. Category B includes major feeder and short branch circuits such as distribution panels more than 30 feet inside the building or lines that are run for heavy appliances. Category A includes long, branch circuits and all outlets more than 30 feet from Category B locations with wire size ranging from #14AWG to #10AWG.

NOTE:

> It is essential that all surge suppressors for electronic equipment be evaluated based on installation location.

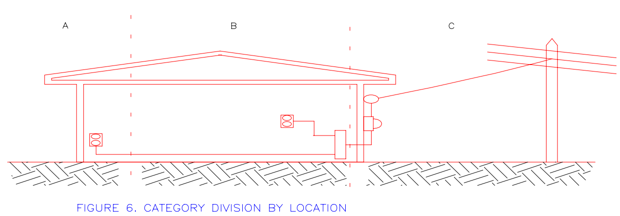


Figure 6: Category Division by Location

Category A

The test waveform for Category A has a 6 kV peak while oscillating at 100 kHz. Each successive voltage peak is approximately 60% of the preceding peak with a maximum impulse current of 200 amps. Refer to Figure 7 for the wave shape.

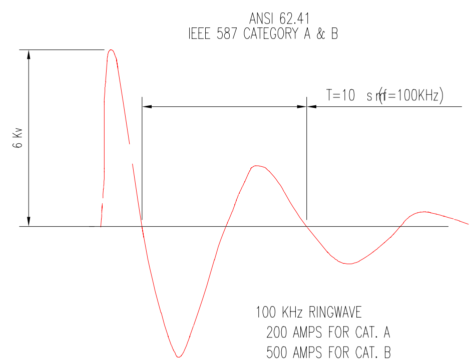


FIGURE 7

Figure 7: Category A and B Waveforms

Category B

The test waveform for Category B actually has two different impulses. The first waveform is similar to the Category A waveform except that the maximum applied impulse current is increased to 500 amps. The wave shape has the same 6 kV zero-to-peak and the 100 kHz ringing effect of Figure 7. The other waveform is referred to as the bi-wave. In this case, there are two individual waveforms. The first waveform is the voltage waveform which consists of a rise time of 1.2 microseconds to 90% of peak and a 50 microsecond fall time to 50% of peak (see Figure 8). The second waveform is the current impulse which has a much slower rise time of 8 microseconds, but a faster fall time of 20 microseconds. *The same point of measurement is true on all waveforms.* The maximum current in this impulse is 3,000 amps (see Figure 9).

FIGURE 8

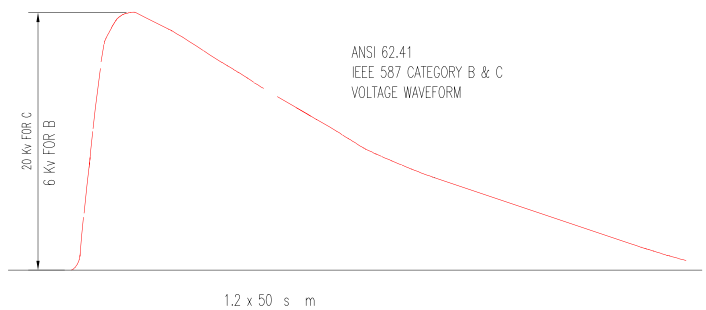


Figure 8: Category B and C Voltage Waveforms

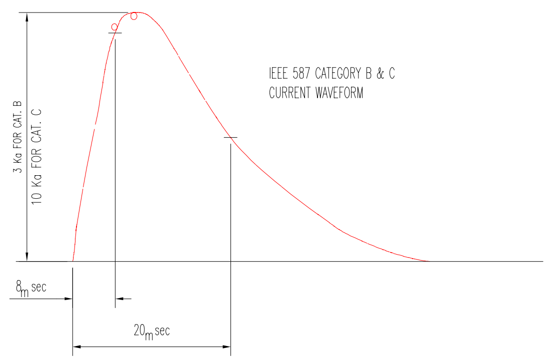


Figure 9: Category B and C Current Waveforms

Category C

The final and most significant waveform is the Category C impulse. Only the bi-wave is associated with this impulse. In this test, the maximum applied voltage is increased to 20 kV for the 1.2 by 50 microsecond waveform (see Figure 8), and the current is elevated to 10,000 amps for the 8 by 20 microsecond waveform (see Figure 9). The obvious reason for the increase is that as the surge gets closer to the source, a greater impulse current is passed through the electrical wires.

The Non-Standard Threat (Category D)

As previously stated, conforming to the standards is not a 100 percent guarantee. The standards are the results of many compromises among the individual contributors (usually the suppliers), and therefore have some built-in risks. These risks are not necessarily intentional, but are not assessed either. This can be corrected by establishing a fourth category for severe risk areas, a Category D that should address the following threats.

Exposure to Direct Strikes

Direct strikes can occur at or near the service entrance, usually in rural areas or on mountaintops. Typical examples are TV and FM transmitters, cellular microwave sites, and similar facilities. Tests for this threat should be based on a worst case direct strike threat with the following characteristics:

Surge Energy	50,000 Joules
Peak Current	200,000 amperes
Rise Time (to 90%)	0.1 microseconds
Transient Pulse Width	20 microseconds

Murphy's Law Situation

Although the unexpected, unusual or "impossible" are rare situations, they do happen and should be given consideration. A simple series fuse of the proper type and in the right location can eliminate this risk. The fuse must be coordinated with the surge protection so that it opens before the surge protector destructs. The only problem occurs when the fuse opens and the protected load loses power in the case where there is no uninterruptible power supply (UPS). But considering the alternative of lost equipment, lost function is the preferred option.

Reliability Impairment

In most surge protection products, the clamping ratio is in direct relationship to the amount of surge current applied. The higher the surge current, the higher the voltage clamp level. It is imperative not to confuse preset clamp voltages with the actual clamp under surge conditions. The required surge condition should be based on the category in which the unit is to be installed. For example, a Category C unit should have a 10,000 amp impulse applied, and then a recording of the waveform should be taken. All recorded data must be sampled using a consistent time based on the type of scope used (somewhere around 20 microseconds). Based on a sample rate of today's scopes, a digital storage scope can give misleading readings. For example, a 2 millisecond sample may reflect only 300 volts zero to peak, whereas the same impulse sampled at 2 microseconds may reflect 500 volts zero to peak.

Radio Frequency Interference (RFI)

RFI is commonly referred to as radio noise. It can enter a facility in a number of ways, including electrostatic activity, magnetic or capacitive coupling, or direct conductance along the AC power line. The most common entry mode is by direct conductance from other sources in the facility. This broad-band noise can create disruptive situations and obscure the signal or create errors in the electronic system. In past years, and in some cases today, 30 dB of attenuation between 10 kHz to 100 mHz solves this problem. However, recent FCC rulings may further increase the attenuation requirements in some parts of the spectrum. Security requirements for the Military Tempest Specification and select industrial applications increase these requirements from 60 to 100 dB of the spectrum and from 10 kHz to 10 gHz. Therefore, in some sensitive applications, adequate filtering is a strategic part of the facility's fail-safe operation.

Protection Concepts

Definitions

Two classes of protectors are used for protecting power lines against lightning related anomalies.

- **Parallel Protectors** These protectors are installed in some parallel configuration between the phase conductor(s) and ground (or neutral). They may include gas tubes, metal oxide varistors, and avalanche diodes. Often, more than one device is used. They are easy to install and relatively inexpensive, but typically involve some compromises in performance.
- **Series Hybrid Protectors** These protectors are installed in series with the phase conductors, with several parallel devices used to dissipate the surge energy and limit the peak voltage. The major benefit is performance. By inserting a series inductor in the power line, a high impedance at mid-range is set to the frequency of the lightning related impulse (average equals 1 MHz). This expedites turning on the primary elements, shunting the bulk of the surge to ground and allowing the secondary protection to clip off any remaining let-through voltage transients.

Protector Evaluation Criteria

The difference in the performance between the various protector concepts is illustrated in Figure 10, using the following definitions:

- **Clamping Point** (CP) or **Clamping Voltage** is the voltage at which the protector *starts* its protective action.
- **Clamping Ratio** is the voltage at the rated peak current divided by the Clamping Point (CP).
- **Reaction Time** is the time between the beginning of the surge (or transient) and the time the protector initiates the protective action.

- **Energy Dissipated** is the volt-ampere-seconds (Joules) of energy that the protector can handle or dissipate in the form of heat without self-destructing.

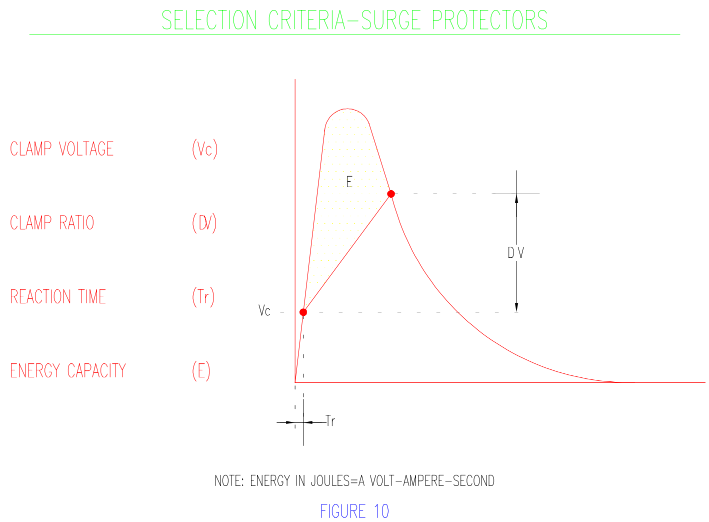


Figure 10: Selection Criteria for Surge Protectors

Parallel Protector Concepts and Options

The Parallel Protector concept (see Figure 11) is so named because it is wired in parallel with the circuit it protects. However, since it is in parallel, it is immediately obvious that whatever appears across the protector (and its wiring) must also be impressed on the load it protects. Therefore, the "protected" must share the surge with the protector. Of course, the protector is supposed to become a very low impedance path in comparison to the protected equipment—*at just the right time*—yet it must not compromise the system performance or waste power.

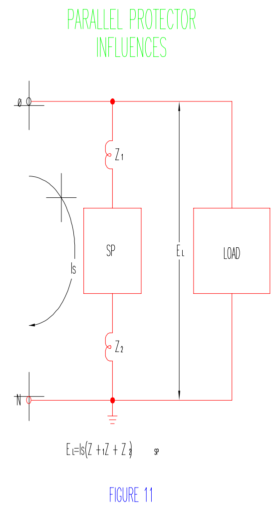


Figure 11: Parallel Protector Influences

The wiring that integrates the parallel protector into the circuit becomes a series impedance to the flow of the fast-rising surge currents (see Figure 12). Rising current rates in the order of 100,000 amperes per microsecond are not uncommon. Under these conditions, each meter of connecting wire may be considered to add between 1 and 1.5 microhenries of inductance to the circuit. The result is a significant series impedance in the circuit, and the voltage developed across these connections adds to the voltage across the "protected" system.

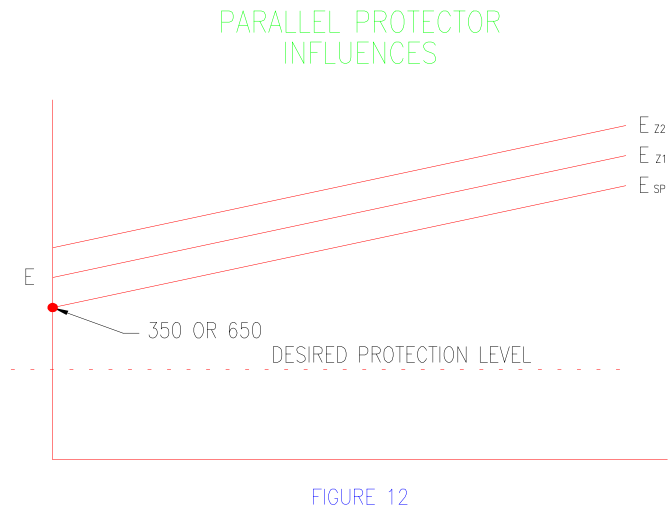


Figure 12: Parallel Protector Influences

Other factors that often compound the problem are the manner in which the surge protector wires are connected into the circuit. For example, the use of metal conduit can compound the problem since this more than doubles the impedance of these connections.

Parallel Protection Devices

Parallel protection devices for secondary level voltages consist of one or more of the following devices:

- **Gas Tubes** are made of one or more gases pressurized in a ceramic or glass tube with electrodes on either side. When the voltage on the electrode achieves a given level, the gas ionizes and the voltage across the electrodes stabilizes at about 40 volts peak until the voltage is reduced to zero. If a manufacturer designs a tube correctly, the device can withstand current surges of over 50,000 amps (8 by 20 microseconds). A gas tube can handle a significant amount of impulse current, but its response time is equal to about 1 microsecond per kilovolt. This tends to be too slow for many of today's sensitive electronics. In addition, the "crowbarring" effect of the AC cycle for up to 8 milliseconds can create a tremendous amount of AC follow-on current. This also depends on source impedance. If the Design Engineer is aware of these deficiencies, additions to the overall circuit can be included to counteract these characteristics.

- **Metal Oxide Varistors (MOV’s)** are effective non-linear resistors made of either zinc oxide or silica carbide. They are usually passive, with very little parasitic loss until the threshold voltage is reached. At that point, the varistor impedance changes many orders of magnitude from a near open circuit to a highly conductive level, thereby clamping the voltage at a pre-selected level. As a general rule, MOV's are very effective when specified properly. The preferred locations for using these products are at Category A and B locations, not Category C locations.

  One of the performance characteristics of the MOV is that the clamp level is in direct relationship to the amount of impulse current applied. The greater the impulse current, the higher the clamp level. If stressed too hard, the MOV degrades or even fails. The failure mode tends to be a shorting effect through the MOV causing small explosions or even a fire. To prevent this destructive fail mode, a series fuse link must be added. If sized correctly, the fuse will open just before the shorting point. The details of this configuration depend on the source impedance and circuit breaker operation. These devices are available in voltages starting at 5 volts to very high transmission line voltages in the hundreds of kilovolts.

- **Avalanche Diodes** are diodes, as the name implies, but of an unconventional nature. These devices perform similarly to the MOV but with some significant differences. They handle much less energy, their clamping ratio is much lower, and the turn-on voltage is much sharper. Typically, the device always clamps at a preset voltage until it fails. The failure mode is much the same as that of the MOV (shorting until the component opens) but does not have the same degrading effect. They are available in voltage ranges from a low of 7.5 volts to a high of 200 volts peak.

- **Selenium Rectifiers** are a very old technology used to provide a parallel form of surge protection. These devices offer no advantages over the foregoing, except possibly price. They operate similarly to the avalanche diode but have an imprecise turn-on voltage. They dissipate more energy, but display a much higher clamping ratio. The one possible advantage is when they are over-stressed, they flashover and often self-heal if the over-stress is not significant and is removed. Considering today's sensitive electronics, by the time the clamp level is achieved or flashover occurs, the protection equipment has been subjected to substantial let-through voltage often causing electronic failure.

- **Hub-and-Spoke Design** is a more recent innovation in TVSS protection. This uses MOV components but configured on a printed circuit board in the form of a wagon wheel, or hub-and-spoke design. This patented surge protection uses a parallel, coaxial array of fused MOV's. Effective current sharing by each MOV results in a 99% plus performance efficiency factor. The results of this configuration are a lower clamp voltage and a higher surge current capability than the traditional surge protection circuits.
- **Sandwich Block™ Direct Buss Technology** is the newest state-of-the-art TVSS protection with the most advanced surge protection component since the MOV. These components use specially designed, large MOV wafers configured or "sandwiched" inside a weather-resistant silicon insulation and rugged aluminum casing. These components are designed for ultra-fast reaction time, low clamp ratio and high reliability. The modular concept keeps the footprint small while the integral heat sink dissipates heat efficiently. The Sandwich Block concept provides a high speed, direct buss interface between the components in the block, allowing each MOV's full face™ to see current at the exact same time while handling multiple and continuous high energy impulses very quickly. The expected life of the module is greater than four times that of other types of components. With energy handling capabilities from 25k to over 50k Joules, this module is designed for extended service while the MTBF of the protected equipment is maximized. It is available in configurations from 120 volts to 4160 volts and split and three phase devices up to 500,000 surge current amps per phase.

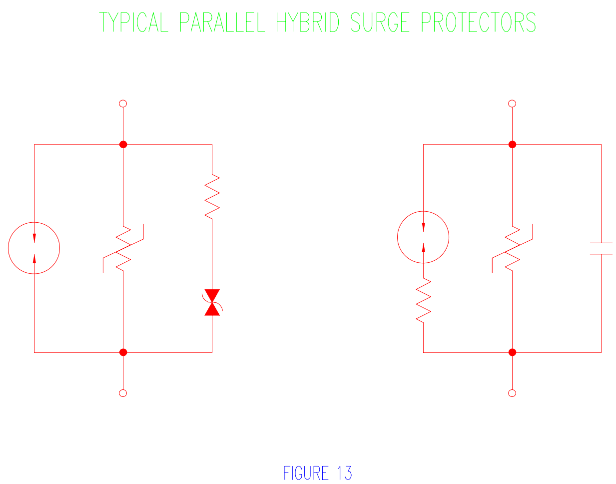
Other technologies have been and are being used. Each one offers some small advantage but can suffer from significant limitations. Typical of these is the sine wave following circuits. They provide clean waveforms but handle little surge energy. They are useful as secondary protection for Category A applications, installed downstream of the primary protector.

Parallel Hybrid Protectors

Parallel hybrid protectors are protection systems that combine parallel devices in some combination with other devices to overcome the disadvantages of the individual components. Figure 13 illustrates some of the combinations available. Each offers significant improvement over the use of a single device. However, they all suffer from the one disadvantage illustrated by Figure 12, the use of the parallel installation format.

Therefore, these combinations do not offer any significant reliability preservation.

Figure 13: Typical Parallel Hybrid Surge Protectors



Series Hybrid Protectors

The series hybrid protectors (SHP) were developed in 1975 to overcome the disadvantages of parallel protectors and provide a protection system that guarantees to prevent both loss of equipment and reduced reliability that may result from the passage of any form of anomalous transient voltage, regardless of the cause.

A series hybrid protector derives its advantage through the use of some form of series impedance that discriminates between the normal line frequency and those in the potential transient spectrums. When the SHP's are installed within the secondary service circuits, as illustrated by Figure 14, the load is actually isolated from transient phenomena. The SHP eliminates the high clamping ratio, because the series element is designed to temporarily impede the flow of high frequency energy giving the parallel elements time to react, thus permitting clamping ratios of 1.2 to 1.

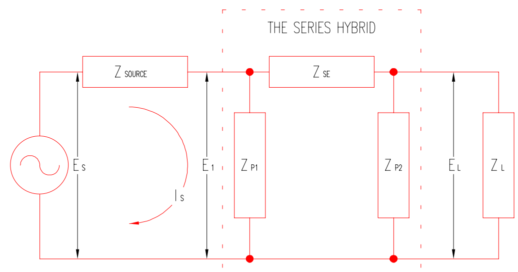


Figure 14: Load Isolation Through the Series Hybrid

The SHP permits the reduction of the initial clamping voltage by isolating the fast-acting but low-energy handling components from the main surge energy. As a result, SHP's are subjected to very low surge energies, and the load experiences very low transient voltages that are well within their design margin, as illustrated by Figure 15.

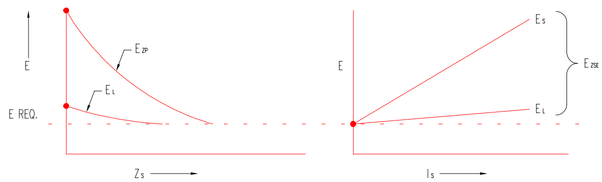


Figure 15: SHP Performance During Overvoltage Conditions

The Series Hybrid Equivalent

It has been shown that the series hybrid form of surge protection is the most effective. It can deal with any form of transient phenomena when properly designed and installed. The series elements are what make the difference. However, as the current carrying demands on the series elements increase, the product cost increases significantly. At service currents above 500 amperes, the market becomes severely limited because of price.

Facilities that demand high service currents are usually large facilities with multiple users on the same floor or on multiple levels. It is necessary to electrically isolate these multiple users from each other. By isolating distribution points with individual protectors, any transient generated by other intra-building equipment outside that distribution point is suppressed. Since separate services are impractical, this leads to the application of one of two options:

- A Series Hybrid Protector for each user in the facility.
- Some form of multi-stage protection.

Since the high-energy surges only appear at the service entrance, high-energy surge protection is only required at the service entrance. Conversely, protection against lower voltage transients and RFI isolation are required at the user level. Fortunately, there is usually a significant length of wiring between any two users in the facility, and between them and the service entrance.

Figure 16 illustrates a typical multiple distribution point in a complex facility situation. Since each meter of wire used in a typical situation equals approximately one microhenry—and may be over twice that if the wire is routed in metal conduit—the inductance between any two distribution points in a facility will most likely exceed 100 microhenries. One hundred microhenries present an impedance in excess of 600 ohms to the lightning related frequency spectrum (1 MHz on average) and much more to the usually higher RFI spectrum.

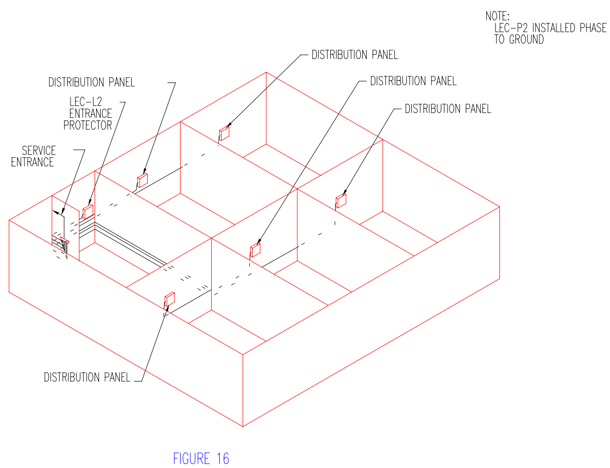


Figure 16: Typical Multiple Distribution Points

The situation described is ideal for the creation of a Series Hybrid Equivalent System (SHES). A SHES is a design concept which configures the building surge protection or power conditioning system by taking advantage of the internal wiring. This can take several forms. The basic concept is illustrated by Figures 17 and 18, where two- and three-stage protection systems are illustrated. Experience has shown that the SHES form of protection used in a relatively modest sized facility provides a better working environment for electronics than any other approach.

Figure 17 illustrates a prime example of using the conduit between the service entrance and the individual distribution point. In most cases, cost can be reduced and performance improved by implementing this design concept. However, the key to a successful SHES is the protection modules used to implement the concept. The two parallel protection modules must be able to perform the two respective functions under worst case conditions and provide minimum reliability while doing so.

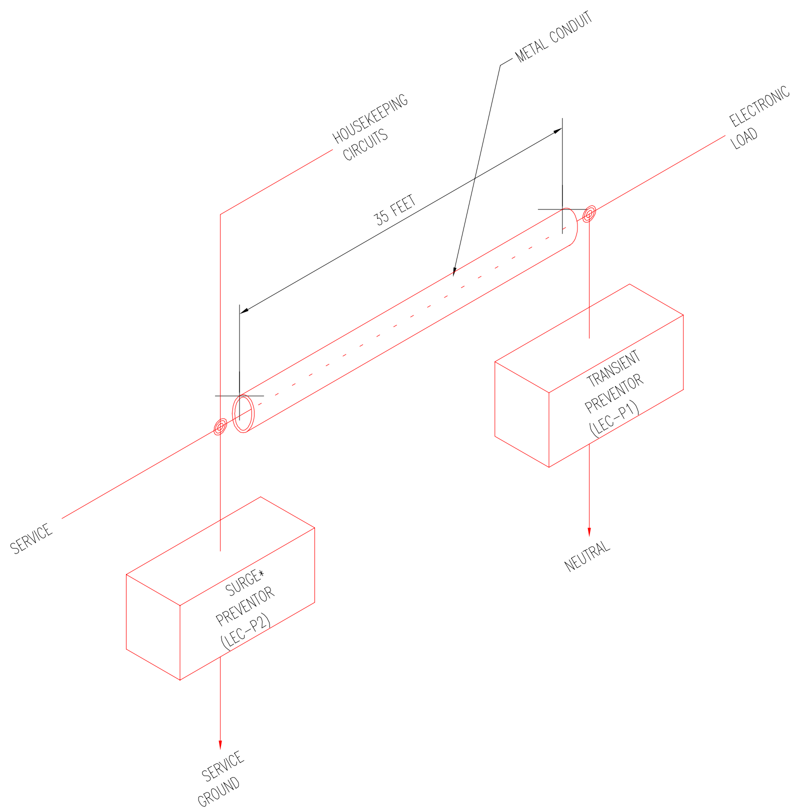


Figure 17: Synthesized Series Hybrid Protector

As an example, Figure 18 illustrates a SHES implemented in its simplest form. All housekeeping circuits are protected with the SP-C, and the SP-B is protecting the sensitive technical panels. This system provides the maximum required surge energy handling capability with the SP-C. The voltage control requirement is met by the SP-B installed at each critical distribution point. Note, that it is not necessary to implement the second stage of protection for the housekeeping circuits as these are far less sensitive.

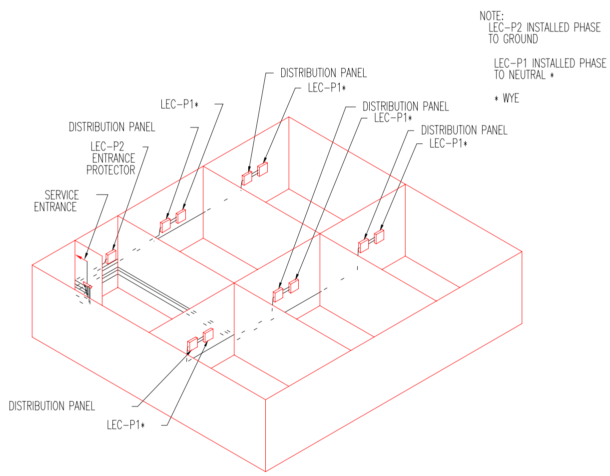


FIGURE 18

Figure 18: SHES Implementation Example

Protectors With Filtering (Conditioned Power)

Definition

Conditioned power is a source of electrical energy that is free of surges, transients and RFI that would otherwise induce immediate or long-term damage. Conditioned power does not impair long-term reliability nor introduce any potential interference, interruption or error into system operations.

The term "conditioned" power implies that the electrical energy is in need of some form of change or improvement. A review of Figure 4 reveals that most of the conditioning requirements involve removing such voltage anomalies as surges, transients, and radio frequency interference (RFI). Since both loss of power and power brownouts make up such a small portion of the spectrum of anomalies, they can be ignored for most applications. Further, the cost of compensating for these low risk anomalies cannot be justified for most applications.

Isolation Transformers

For several decades, the Isolation Transformer family has been used as the "cure all" for power conditioning requirements. They were the only technology available for this purpose for many years, and they did solve the problems of the 1950's. However, with the advent of more sophisticated electronics, they became inadequate for many applications. Isolation Transformers became less and less useful for modern, complex and sensitive installations.

To overcome this inadequacy, manufacturers introduced a series of design changes to improve the Isolation Transformer’s usefulness. The three major steps introduced to improve their isolation qualities are illustrated by Figure 19. Note that all of these changes involved improvements in the RFI rejection qualities (RFI shielding as well as some filtering). None involved improvements to provide lightning or surge protection. A typical specification from an Isolation Transformer manufacturer ranges from 60 dB of common mode and 30 dB of normal mode noise attenuation for a conventional Isolation Transformer, to 140 dB of common mode and 60 dB of normal mode noise attenuation for an Ultra-Isolation Transformer.

A major point of concern is knowing at what point in the spectrum the 140 dB occurs. For the common and normal mode noise specifications, the manufacturers' data no longer provides curves. Therefore, one must assume that the 140 dB occurs at only one point. Another concern is the frequency of the common mode, which runs from about 1 Hz to 10 MHz, while the normal mode occurs between about 10 KHz to 30 MHz. This rejection spectrum is not significant. At the high frequency end, the filter is not considered broad enough. Contemporary requirements demand filtering into the GHz range. As an additional shield is introduced, the efficiency of the transformer is reduced, as well as adding heat into a controlled environment. This could increase the required capacity for the Environmental Control System. When the shielding of an Isolation Transformer is increased, substantial audible noise is added into the work place.

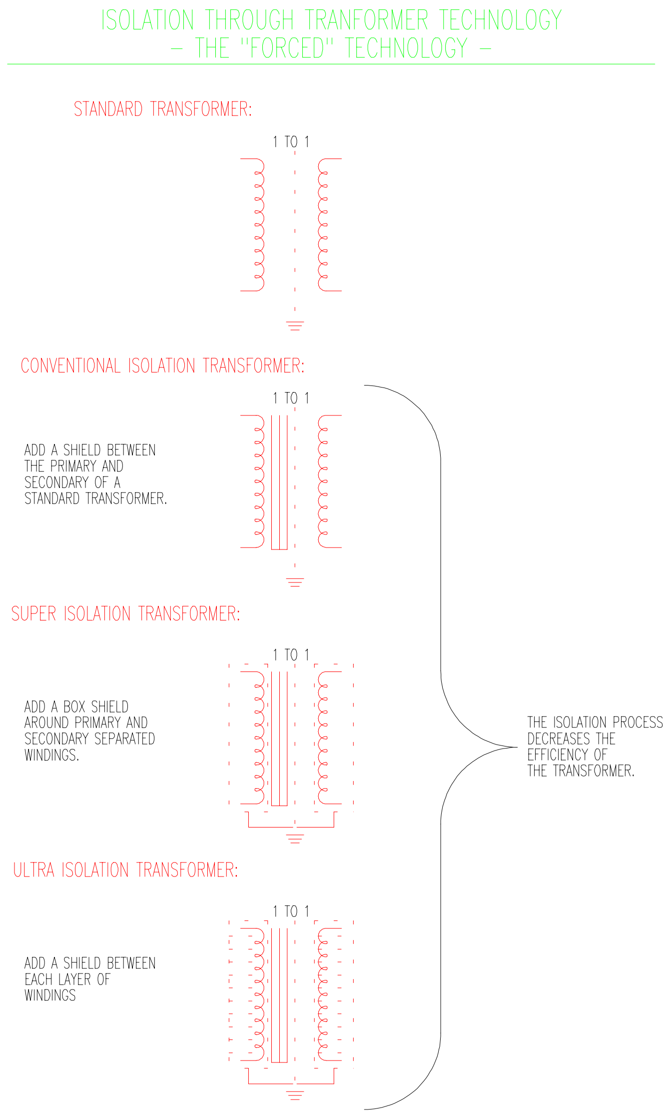


FIGURE 19

Figure 19: Isolation Through Transformer Technology

Although it is true that Isolation Transformers have eliminated or reduced some voltage anomaly problems, it is also true that those functions could have been accomplished through the use of a conventional technology designed to perform the specific tasks at a much lower cost. The steps required are as follows:

1.	Prevent surges	Use a surge protector.
2.	Eliminate RFI	Use a conventional tee or wye filter.
3.	Eliminate noise	Use a noise stripper.

No parallel form of device alone will accomplish these objectives.