# An Important Link in Whole-House Protection: Surge Reference Equalizers

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Significance
Part 6: Tutorials, textbooks, and reviews
Part 7: Mitigation techniques

Explains several scenarios of interactions between surges impinging at one of the ports of two-port equipment, resulting in a damaging or upsetting shift of the potential differences between the “reference” of each port, which are normally presumed to be at the same potential (“ground”)

Offers two solutions and additional remedies, with a discussion of system compatibility criteria.

# AN IMPORTANT LINK IN WHOLE-HOUSE PROTECTION: SURGE REFERENCE EQUALIZERS

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**Abstract** - The increasing use of electronics in residential applications has been paralleled by a realization that surge protection may be necessary for this type of equipment. Installing a surge-protective device on the power-line port as well as on the communications-line port of an equipment might appear sufficient to ensure this protection. However, the normal operation of one of the protective devices during a surge event can create differences in the voltages of the references of the two ports. This difference in voltages, applied across the equipment or across a communication link between two pieces of equipment, can result in permanent damage as well as upset. Equalizing these voltages can be achieved by proper routing of the two lines through a single device, called *Surge Reference Equalizer*, and thus avoid the risk of damage.

## THE PROBLEM

A new generation of smart electronics has emerged that involve processing information obtained from communication networks: fax and telephone answering machines connected to the telephone system, television sets connected to a cable system, desk-top publishing systems connecting several computers and printers, industrial process controls with remote sensors and terminals, etc. This type of equipment generally requires a metallic connection to the communications system, while being powered through a connection to the local power system. This dual connection introduces a risk of interference or damage to the equipment because, during surge events, the two systems can have differences in the voltage of the two systems reference points.

In the consumer world, damage is the greatest concern, upset may be tolerable; in the commercial and industrial world, upset and its consequences are already unacceptable. Understanding the topology of the equipment and of its connections to the power and communications networks, as well as the mode of propagation of surges in the two systems, will help in defining appropriate solutions and avoiding counter-productive situations.

A useful concept is to envision the relationship of any electrical equipment to its electromagnetic environment by means of several 'ports'. According to this concept, 'port' means a point of access where energy may be supplied or withdrawn. In the most general case, six types of ports can be identified, as shown in Figure 1. The desirable signals (including power) as well as undesirable signals can enter or leave the equipment through these ports. Five of them involve metallic connections, that is, cables (with the exception of fiber optics links). The sixth is electromagnetic coupling through the equipment enclosure, directly into or out of the equipment inner circuits.

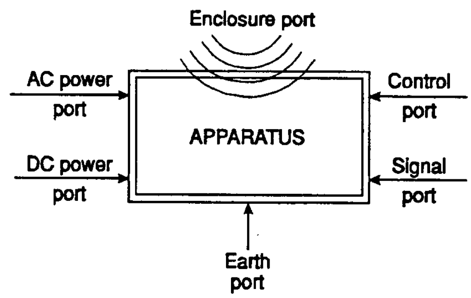


**Figure 1 - Six ports for coupling of disturbances from electromagnetic environment to equipment**

The general case of Figure 1 shows a separate 'earth port'. In typical situations, this port can be a distinct, direct connection to the local grounding system, or it can be included in the connection of the other ports, such as the equipment grounding conductor of the power line or the shield of the cable TV connection. In computer-based systems, signal cables usually include a 'signal reference' conductor which is connected to the equipment chassis and, therefore, ultimately to the equipment grounding conductor of the power cord. Typical smart electronics equipment have at least two ports, the ac power port and a communications port.

In one scenario, a reasonably well-informed end-user might have provided surge protection on both the power port and the communications port, yet the equipment could be damaged by a difference in the reference voltages developed during a surge event.

Figure 2 shows such an arrangement, where the telephone port of the Fax machine is assumed by the end-user to be protected, thanks to the Network Interface Device (NID) installed by the telephone company, and the power port is also expected to be protected by the plug-in surge-protective device installed by the surge-conscious end-user. Such a plug-in device is often called *Transient Voltage Surge Suppressor*, TVSS for short in the U.S., but is now recognized by the acronym *SPD* by the International Electrotechnical Commission.

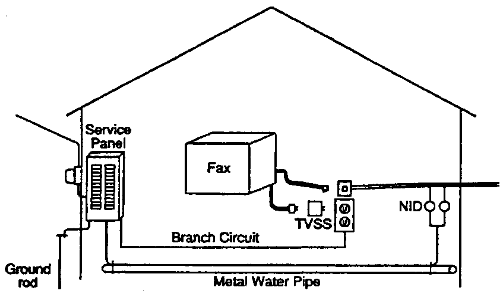


**Figure 2 - Incomplete protection of two-port equipment, in spite of having two protectors**

If a surge impinges upon the building at the power or the telephone port, the expected operation of the protective devices will divert the surge current to ground ('protective earth' in European terminology). The voltage drop caused by the fast-changing surge current flowing in the inductive ground connection of the protective device leaves the line connection of the surge-carrying system at a voltage higher than that of the system unaffected by the surge. A difference of voltage appears across the two equipment ports during the surge event, in particular during the rise time. This difference of voltage can cause an upset or hard failure if the equipment has not been specifically designed for that stress. Thus, separate, uncoordinated protection of each of the two ports can still leave the equipment at risk.

Another scenario involves the voltage difference between the two chassis (and thus the signal reference) of sub-units powered from different branch circuits, as shown in Figure 3. In this scenario, a built-in SPD or EMI filter has been provided in each sub-unit by a prudent manufacturer. The normal operation of the SPD or EMI filter during a surge event causes a voltage drop in the conductor that returns the surge towards the service entrance. Meanwhile, the chassis of the other sub-unit, unaffected by the surge, remains at the voltage of the service entrance reference. The result is that the two chassis assume different transient voltages, and the data link reference conductor connected to these two chassis will attempt to equalize the voltages, with possible upsetting or damaging consequences to components in the line driver or receiver circuits of the two sub-units.

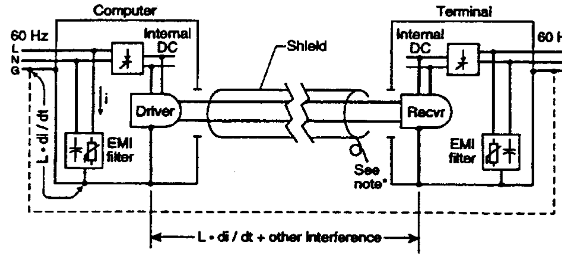


**Figure 3 - Injecting voltage differences in a data link by normal operation of the SPD or EMI filter**

## TWO SOLUTIONS

The radical, well-known solution for this type of problem is to provide a fiber optic communications link rather than a metallic connection. This solution is frequently applied to solve problems in utilities, industrial or commercial installations, but its relative complication and present cost have kept it impractical for residential, consumer-type applications. In such cases, another solution is a ***Surge Reference Equalizer***. The generic name of this device has been introduced by a new IEEE standard [IEEE 1100], giving recognition to a concept that has emerged over the last several years.

The surge reference equalizer combines the protective function for both system ports in the same enclosure. The device is plugged in the power receptacle near the equipment to be protected, with the communications system wires (telephone or data link) or the coaxial cable (TV) routed through the enclosure. A common, single grounding connection equalizes the voltages of the two paths that return the surge through the grounding connection of the 3-prong power line plug, as shown in Figure 4.

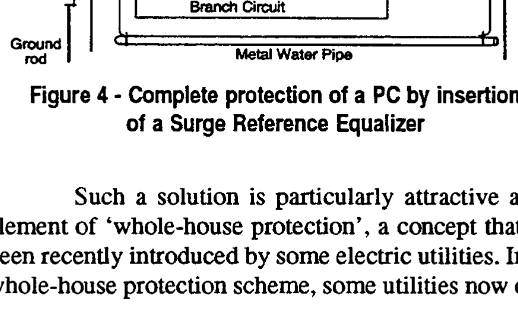


**Figure 4 - Complete protection of a PC by insertion of a Surge Reference Equalizer**

Such a solution is particularly attractive as an element of 'whole-house protection', a concept that has been recently introduced by some electric utilities. In the whole-house protection scheme, some utilities now offer an engineered, coordinated installation of SPDs to their customers [Maher, 1991], instead of the do-it-yourself approach that can lead to the situation illustrated by Figure 2. Several locations can be considered for connecting these SPDs, as shown by the numbered SPD locations in Figure 5. In the whole-house protection scheme, a two-step approach is used: an SPD is installed by the utility at the service entrance (location 2), and plug-in SPDs are supplied by the utility to the consumer for insertion on the input ports to sensitive equipment within the residence (location 6).

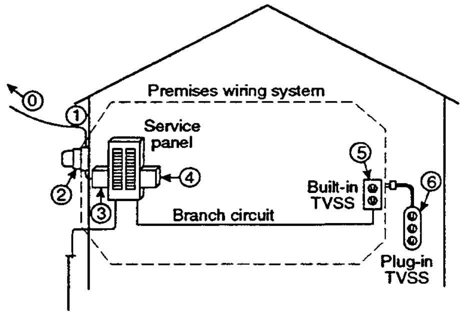


**Figure 5 - Possible locations for SPDs in a residence**

The objective of the two-step protection scheme is to divert most of the impinging surge energy at the service entrance, and to complete the protection at the point of use by a plug-in SPD. This second device can then serve as surge reference equalizer, rather than serve only as a TVSS on the power port.

Surge reference equalizers are now found in electronics and computer stores, although neither the name nor the design have been standardized. The intended function can be immediately recognized by the presence on the enclosure of a power route - a male plug and one or more female receptacles - and a communications route - cable TV coax fittings, telephone jacks, or RS232 connectors. Until the voluntary standards process has fostered uniform characteristics, the performance of these devices can vary from one brand to another, although one could expect each manufacturer to have made reasonable assumptions and tradeoffs in the design of the product. An alert consumer who is considering on his own the purchase of such a surge reference equalizer has no information on the performance or side-effects of what the store-bought device offers. An engineered scheme offered by the utilities can provide the leverage to obtain devices with demonstrated performance.

## SYSTEM-COMPATIBILITY CRITERIA

The rapid development and marketing of these surge reference equalizers has left the process of voluntary standards development behind. At this point, there is no available standard to assess the performance and compatibility of these devices. For instance, the immunity level of the input UHF circuitry of a TV receiver or recorder is not specified by industry standards, leaving the designers of surge reference equalizers in the dark as to what level of surge suppression they should provide in their devices.

Fueled by the desire of electric utilities to provide enhanced power quality to their customers by supplying appropriate SPDs, the response of EPRI has been to sponsor the development of test protocols for assessing the system compatibility of these devices. The approach consists in performing tests on devices proposed for installation in the residential environment in accordance with a set of consistent and objective criteria taking into consideration the surge environment, the needs for protection of consumer electronics, and the need of the electric utility for compatibility with its power delivery system.

In fact, the concept of providing test protocols for assessing compatibility of equipment extends far beyond the specialized domain of the surge reference equalizers discussed in the present paper. The Power Electronic Applications Center (PEAC), sponsored by EPRI, is currently developing a family of test protocols for equipment such as fluorescent ballasts, adjustable speed drives, enhanced computer power supplies, etc.

## TESTING FOR SYSTEM COMPATIBILITY

Tests for system compatibility of several surge reference equalizers were performed at PEAC on devices proposed for a "Whole-House" protection plan by an electric utility. The following brief review of the test results illustrates the benefit of the program in identifying adequate performance as well as needs for improvements in the performance.

The tests were performed in accordance with the test protocol [SC-120]. These tests include a determination of the clamping voltage on both power and communications ports, an assessment of durability, and checking for side effects. A unique aspect of the SC test protocols is that while expected results are stated, the tests results are not presented as pass/fail, but rather as a comparison between expectations and results, leaving room for the sponsor to make a decision based on the overall performance.

Two sets of candidate surge reference equalizers were tested at PEAC. One set featured power port and telephone port protection, the other power port and cable TV protection. For telephone-port devices, the various designs were based on a multi-stage circuit connected between each of the two conductors of the telephone cable and ground. For TV-port devices, different design principles were apparent among the manufacturers. Some had a solid connection between the shield of the TV signal cable, others had this connection made through a surge-suppressing component; all had a gas tube for protection between the center conductor and the shield of the coaxial cable.

For the telephone ports, industry standards [ANSI/EIA/TIA 571], used as the basis for the SC-120 protocol, specify a surge-handling capability of 100 and 200 A with a 10/1000 μs waveform. All devices could discharge the 100 A surge, but only one could discharge the 200 A without damage. The let-through voltages ranged from 230 V to 560 V, levels that are compatible with immunity levels of typical telephone equipment.

A regulatory requirement for telephone protectors is that in the event of a power-cross (injection of power-frequency voltage on the telephone wiring), the resulting power-frequency current must be limited or interrupted before the telephone wiring in the residence overheats dangerously. Surprisingly, this requirement was not satisfied. At this point, the concept of system-compatibility testing provides an avenue for remedy rather than rejection: the tests are conducted with the knowledge of the manufacturers and deficiencies in performance can be corrected by the manufacturer before they become an issue leading to outright rejection of an otherwise attractive product.

The immunity levels of cable TV ports are not characterized by published industry standards, and thus it is difficult to define performance expectations for the devices intended to protect these ports. The PEAC tests were performed to determine the clamping level with an impinging surge of 1 kV peak, ringing at 100 kHz, and 33 A peak available short circuit. The let-trough voltages ranged from 50 V to 1000 V, leaving open the question of adequate protection. Efforts will be continued in obtaining the cooperation of the electronics industry in defining the immunity levels of the TV port.

Functional and regulatory requirements for a TV-port device include freedom from signal leakage and degradation through insertion loss or interference. All devices were found satisfactory in this regard.

## ADDITIONAL REMEDIES

The problem of threatening voltage differences created along the return path of a surge diverted at the end of a branch circuit can also be reduced by other means. High-current surges on the power system originating outside of the user's premises, associated with lightning or major power-system events, are best diverted at the service entrance of the premises. While such a protection is not mandated at present, trends indicate growing interest in this type of surge protection. Either the utility or the end-user may provide a high-energy surge arrester at the service entrance.

In such a scheme, external surges are diverted at the service entrance and no longer flow in the building in search of a small protective device installed at the end of a branch circuit. There are still surges generated within the premises, but these have lower current levels and can be diverted by protective devices located close to the internal surge source or close to the sensitive equipment, for instance by the surge reference equalizers. This possibility of dual protection raises the issue of coordination of cascaded devices, an emerging concern in the application of SPDs in the power system of end-user facilities [Lai & Martzloff, 1991]. The clamping voltages of the service entrance arrester and of the surge reference equalizer must be coordinated so that the low-energy surge reference equalizer will not attempt to divert large surges that the high-energy surge arrester is expected to intercept.

## CONCLUSIONS

The rapid expansion of smart electronics involving power and communications connections creates the potential for disappointing performance under surge conditions if adequate, coordinated protection is not provided. Separate, uncoordinated surge protection of each of the two ports still leaves the possibility of damage or upset.

A new type of device, the 'Surge Reference Equalizer', offers a solution to the problem, provided that the performance characteristics of the device will be coordinated with the environmental stress and with other surge-protective devices that may be installed on the systems.

System-compatibility tests performed on several proposed surge reference equalizers show that their performance characteristics vary from adequate to questionable (even unacceptable when regulatory safety requirements were not satisfied). However, as a result of the basic concept of the test program, these deficiencies in performance can be recognized in time and corrective action taken before the devices are broadly applied. In this manner, both the consumer and the electric utility can be confident in their expectation of effective protection of the residential electronics.

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