

What Are the Lights on Your Surge Protector Telling You?

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Especially in a free market, sensible standards and reasonable regulations have a role to play toward providing useful, reliable and safe consumer products, such as the now familiar transient voltage surge suppressors (TVSS). However, the definition of what is sensible and reasonable has not been stipulated in any TVSS standard. This article provides a historical perspective of the evolution of how TVSS standards address the issue of a disconnecter, an emerging concept in TVSS design.

A sampling of how this concept has been implemented by the TVSS industry, including overcurrent protective devices (fuses) and thermal runaway protection (thermal cut-out), shows a variety of rather confusing approaches. To illustrate this point, let's consider three familiar products: fruit cakes, automobiles, and TVSSs.

We will all agree that our military personnel serving in some desolate foreign country are entitled to a high-quality product when the traditional fruit cake is sent to them at holiday time. To ensure that this happens, as reported tongue-in-cheek by the media a few years ago, a lengthy specification had been developed for quality-control in the procurement of fruit cakes.

Consider now the plight of the tired traveler, arriving at night in an unfamiliar airport and renting a car. The agent behind the counter gives the traveler the keys and the location of the car in the parking lot, and smiles with good wishes

thrown into the deal. Arriving at the designated spot in the dark parking lot, everyone expects to find that the steering is located on the left, controlled by means of a wheel, the engine is started with an ignition key, generally near the steering column, and gas and brakes are controlled by the right foot. But what about finding the headlight control after you have closed the door (it's cold and windy out)? Worse yet, two miles out of the airport, in heavy traffic, it suddenly starts to rain and the traveler fumbles to find the windshield wiper control? Now would it not be lovely if there were standards mandating the location of these controls?

No Common Meaning to Lights

Coming now to the point of TVSS, consider the plight of the consumer who bought a TVSS, and discarded the bubble package or misplaced the instruction sheet. This consumer is now trying to find the meaning of the pilot

light, or pilot lights, indicating the state of the device – specifically whether protection is in effect or protection is lost. The original 1985 version of UL Standard 1449 stipulated that a visible or other indication of the protection status must be provided when an overcurrent protection has operated. But that is no help to the computer user who has installed a plug-in suppressor sandwiched between the wall and the desk. Even if the TVSS is visible, there might be one, two or even three pilot lights, with or without clear and reliable indication of their meaning.

To place this undesirable situation in perspective, I visited three local electronics and do-it-yourself stores and bought 17 different brands of TVSSs. The question was, "How would the user be informed on the status of protection after a temporary overvoltage caused failure of the protective element in the TVSS package?" A temporary overvoltage was selected as the method of failure because there is growing evidence that they cause a large number of the failures – perhaps the majority – rather than "large" surges. Although that statement could be the subject of one entire issue of this magazine, it is only mentioned here to describe how the failures were obtained.

The point of the inquiry was not to describe how the failure occurred (in particular whether there was a potential hazard, since the devices were manufactured before the 1996 Second Edition of UL 1449 became effective). The point of the inquiry is to find what information is clearly conveyed to the user after the TVSS has failed, and its

disconnecter has operated. Neither the new UL 1449, nor any IEEE or IEC standards address that practical question. In fact, the new 1996 version of UL 1449 no longer stipulates inclusion of a visible indication. As it turned out, several of the packages among the 17 specimens had very little information on the significance of the indicating light or how the indications should be interpreted. Furthermore, as mentioned earlier, once the bubble package is discarded, the information is lost, because it is unlikely the typical user will safeguard the back of the bubble package where the details – if any – might have appeared.

SPD Failure Modes

Surge-protective devices (SPDs) components – switching away from the jargon ‘TVSS’ to the official term of ‘SPD’ approved by the IEEE and IEC – like any electrical component, are subject to failure for a variety of causes including severe overstress beyond their

rating, natural aging, premature failure caused by misapplication, etc. The outcome of such failures ranges from an open circuit to a very low impedance, but rarely a zero-impedance short circuit. A final open circuit may be difficult to achieve in an environment of high available fault current. If achieved, it implies loss of protection against subsequent surges. A zero-impedance condition would mean no energy dissipation (no heating) in the failed SPD component and thus a relatively benign failure mode from the point of view of the SPD environment, but that would require interruption by an upstream overcurrent protection device.

In reality, the nature of the failure mechanism, in particular for metal-oxide varistors, (MOVs) is that the impedance of the failed SPD, which is resistive, is low, but not zero. Consequently, the power circuit will deliver to this medium-range resistance a current which will involve significant energy, depending upon the actual resistance of

the failed device and the upstream impedance of the power system.

If left unabated, this deposited energy will produce severe overheating with attendant risk of fire or other objectionable failure modes. It is to prevent such objectionable scenarios that the concept of an SPD disconnecter emerged, as seen in this historical perspective.

The term “disconnecter” is a recent addition to the vocabulary of the SPD industry, and the spell-checker of most word processors flags it as unknown (as if your processor had never disconnected on you?). Even the definition of the term has gone through several iterations in recent years.

According to emerging standards, the disconnecter function is to “disconnect an SPD from the power system in case of SPD failure.” This clear and simple concept, however, has not been consistently implemented by industry, in particular by the low-voltage SPD industry. In particular, two different devices

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SPD Indicator Lights

Document	Text	Remarks
1976 GE Transient Suppression Manual First Edition	There are two possible sequences of events leading to failure ... Accordingly, and in keeping with good safety practices, the varistor should be placed following the equipment fuse ...	First mention that a fuse should be used in conjunction with an SPD.
1978 GE Transient Suppression Manual Second Edition	... the careful designer may wish to plan for potential failure modes ... mechanical rupture of the package accompanied by expulsion ... minimize this potential hazard by fusing to limit high fault currents and locating varistor away from other components ...	The guidance is becoming more specific, but this was still a recommendation, not a mandate.
1985 UL 1449 Transient Voltage Surge Suppressors, First Edition	12. Supplementary Protection "A transient voltage surge suppressor that is provided with supplementary overcurrent protection in series with the suppressor shall also be provided with visual or audible indication or both of the opening of the protection device." Exception: not required if in series with the load terminals	Implies the existence of a disconnecter function but does not mandate it.
1987 C62.11 - IEEE Standard for metal-oxide surge arresters for alternating current power circuits.	Arrester Disconnecter A means for disconnecting an arrester in anticipation of, or after, a failure in order to prevent a permanent fault on the circuit and to give indication of a failed arrester Note- Clearing of the fault current through the arrester during disconnection is generally done by the nearest source side overcurrent protective device.	The word "arrester" in the title is unlikely to attract the attention of low-voltage SPD users. The note allows shifting the function to a separate device (presumed to be existing).
1994 IEC 37A LV SPDs Working Group Draft - SPD Selection and Application Principles	SPD Disconnecter A Device for disconnecting an SPD from the power system in case of SPD failure. At least three functions are needed ... They may be integrated in the SPD ... or integrated to another part ... They may be used in the SPD circuit or in the mains	Many options offered (Too many to be useful)
1996 UL 1449 Second Edition	3.24 - Supplementary protection device definition: "A device intended for overcurrent protections ... 12 - Supplementary Protection	Has to be replaceable or resettable unless the whole unit is replaceable. Visible or audible indication of operation, stipulated in the 1985 edition, is no longer required.
1996-1997 IEC 61643 SPDs for LV power distribution systems - Performance requirements and testing methods 37A/44/CDV, 37A/63/FDIS	SPD Disconnecter "A device for disconnecting an SPD from the system in the event of SPD failure. It is to prevent a persistent fault on the system and to give visible indication of the SPD failure."	Visible indication of failure is implied as a requirement within this definition.
1997 Proposed modification for 37A/63/FDIS	SPD Disconnecter "An internal or external device required for disconnecting an SPD from the system in the event of SPD failure. It is to prevent a persistent fault on the system and may give visible indication of the SPD failure."	Allows separation of the disconnecter function into a separate device. Note the insertion of "may" in the provision of a visible indication.
2001 ???	Consensus at last	Hopefully, before the turn of the century

Table 1. Brief history of the need for disconnecter function as stated in standards and other references.

— a fuse or a thermal cut-off — can serve toward that end, each covering one type of SPD failure. In case of SPD failure resulting in a low impedance mode (a few ohms) an overcurrent occurs, with amplitudes in excess of the SPD rating, so that a fuse can clear the circuit. In case of a thermal runaway, the beginning of SPD failure, the current is still too low to operate the fuse, but the consequences of failure (overheating) can be prevented by the operation of a thermal cut-out in close proximity to the SPD experiencing the beginning of overheating.

This ambiguity in the type of disconnecter design and the lack of consistency or consensus in the interpretation of the function is apparent in the wide variety of designs found on the market, while standard-writing bodies are still working on developing an acceptable consensus over a broad range of applications. One unresolved issue is whether the user expects protection after failure — through a complete discon-

nect of the load — or would rather take a chance by maintaining continuity of operation, but without protection.

Standards development generally lags the development of products in a competitive, fast-moving technology. Low-voltage SPDs are no exception. To illustrate this point, *Table 1* presents a chronological tabulation of the evolution of the disconnecter concept, from the introduction of metal-oxide varistors in the mid-seventies, to the latest amendment of the definition of a disconnecter in the late nineties.

The tabulation shows the reference document and cites, verbatim or in summary, the implied need — and eventually the specification — for a suitable disconnecter function. Inspection of the chronology shows a clear trend toward mandating a reliable disconnecter function, but also some concessions to existing product practices. Nevertheless, the disconnecter remains the ultimate protection against objectionable failure modes. As recognition of this essential

role of a disconnecter increases, one can expect that standards are more likely to mandate provision of a reliable and clearly defined disconnecter function for all low-voltage SPDs. It may be easy for an outsider to make judgments on the apparent chaos of the marketplace and the present standards, but there are extenuating circumstances because the concept as well as the implementation of a satisfactory disconnecter are not trivial. Some of the options, advantages and drawbacks are briefly enumerated below.

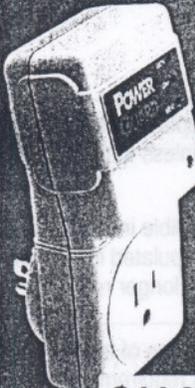
Disconnecter Provisions

Integral disconnecter

⚡ Disconnects only the shunt-connected SPD

- ▲ Design challenge: requirement of not operating for the expected surges but of operating promptly upon failure of the SPD element.
- ▲ User information: necessity to

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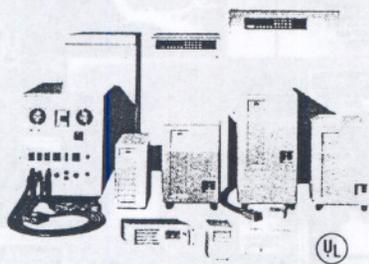
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SPD Indicator Lights

SPD	Status Indication	Continuity	Type of Indication *
1	Protection off	Maintained	Not recommended
2	Protection off	Interrupted	Desirable
3	Protection off	Interrupted	Desirable
4	Protection off	Interrupted	Desirable
5	Protection off	Maintained	Not recommended
6	Protection off	Interrupted	Desirable
7	Protection off	Maintained	Not recommended
8	Protection off	Interrupted	Desirable
9	Protection off	Maintained	Not recommended
10	Protection off	Maintained	Not recommended
11	Protection off	Interrupted	Desirable
12	Protection off	Maintained	Not recommended
13	Protection ON	Maintained	Misleading
14	Protection off	Maintained	Not recommended
15	Protection off	Maintained	Not recommended
16	Protection off	Maintained	Not recommended
17	Protection ON	Maintained	Misleading

* This comment is based on the postulate that the user would prefer to have costly equipment protected, albeit disconnected, rather than have the power supply maintained at the risk of not protecting the equipment.

Table 2. Summary of status indications.

clearly signal that protection against subsequent surges is lost.

- ⚡ Disconnects the SPD and the protected load
 - ▲ Design challenge: respond to abnormal SPD condition (thermal runaway) at current amplitudes below the rating of the SPD.
 - ▲ The necessary steady-state current carrying capacity for the fuse disconnecter allows persistence of limited current faults in the SPD, resulting in hazardous overheating, unless an additional protection is provided by a thermal cut-out.
 - ▲ User information: some users might prefer to maintain operation of the load, albeit with no surge protection. However, if this is the mode provided by the design, it must be clearly identified on the product, and indication of protection loss must be signaled – a mere indicating light on an SPD

installed in a manner that the user will not inspect seems a poor choice for an uninformed user.

External disconnecter designed for the circuit

- ⚡ Protection of the power system is achieved, but the disconnecter is unlikely to respond to limited fault currents below the normal rating of the circuit supplying the SPD. Furthermore, the thermal runaway protection cannot be performed by an external device which is not in close contact with the SPD component.

From the possibilities listed above, it is clear that a reliable disconnecter function is imperative for the successful and safe application of SPDs in power systems. However, market pressures and the resourcefulness of designers result in a wide range of design approaches, which can be overwhelming for the end user, just like our tired traveler arriving at the airport. Beyond the basic function of a low-voltage

SPD disconnecter, the details of the operation and the interpretation of indications provided by all the different manufacturers do not offer a systematic, user-friendly and standardized situation.

To illustrate this point, *Table 2* presents a summary of the visible indications on the 17 blind-purchase of TVSSs, after producing their failure by applying a temporary overvoltage. In this table, it is postulated that for the typical consumer, ensuring protection of expensive equipment is preferable, even if it means that power is cut off for the equipment; in other words, maintaining continuity is undesirable. There may be some applications where maintaining continuity would be the first choice. In either case, a clear indication of which state prevails should be clearly stated. From this table, it is apparent that the two possibilities – maintained continuity or maintained protection – are offered by different manufacturers. However, the implications of this choice were not clearly stated on the package, and

in two instances, the indications were in fact misleading. Hopefully, industry and standards-writing bodies will remedy this situation.

Without invoking a bureaucratic system of regulations, it would seem that a clear consensus among the manufacturers would make the informed end-user much more appreciative of the industry offerings, and provide enhanced safety for the public.

Conclusions

1. A survey of the low-voltage SPD (TVSS) products currently on the market shows not only a variety of disconnecter responses after a failure, but, in some cases, false indication of the protection status.
2. Information provided by several manufacturers, on the product package (soon to be discarded after purchase by the end-user) or on the product itself, fails to give unambiguous information on the status of load pro-

tection after failure of the SPD component.

3. Anecdotal information indicates that devices currently on the market might not be provided with a disconnecter that meets the undefined but expected safety in failure modes. The second edition of UL 1449 is a very constructive step toward a remedy, although it does not address the question of status indication.
4. This uncoordinated – not to say chaotic – situation clearly points to the need for accelerating the development of an industry-wide consensus on the design, operation, and interpretation of the indications of low-voltage SPD disconnecters. Hopefully, this article will help the process.

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