Alternatives for Overvoltage Protection

WADE GILES
Teccor Electronics, Inc.

Overvoltage protection (OVP) is a simple concept, but it is complicated by regulatory requirements and factors such as multiple hits, frequency of occurrence, transient surge currents, and the sizes, shapes and speeds of the potential surge waveforms. This article describes four of the most commonly used OVP devices in the telecommunications industry — gas discharge tubes (GDT), metal oxide varistors (MOV), avalanche diodes and thyristors — and the regulatory requirements that these devices and telecommunications equipment must satisfy.

Transient voltage suppressors provide a unique means of surge protection and offer distinct advantages.

GAS DISCHARGE TUBES

A gas tube can be either a glass or ceramic package filled with an inert gas and capped on each end with an electrode. Like a thyristor, avalanche diode, or MOV, a GDT is connected in parallel with the circuit being protected and has a high off-state impedance. Once a transient voltage exceeds the dc breakdown voltage of the gas tube, the voltage differential between tip and ring fires the gas tube's electrodes, causing an arc. This arc ionizes the inert gas which provides a path of low impedance for the transient to follow. Once the transient drops below the dc holdover voltage and current (typically 60 V and 200 A), the GDT returns to its high off-state impedance.

The benefit of using a gas discharge tube is that it offers a high surge current rating. For a nonrepetitive surge with an 8x20 μsec waveform, a gas tube can withstand up to 20 kA. For a 500-A, 10x1000 μsec waveform, a gas tube can typically withstand up to 200 impulses for a standard device and 1000 impulses for a heavy-duty device. Other benefits of the gas tube include its low capacitance and the availability of a three-leaded package that allows for a tip-ground-ring connection with a single device.

The disadvantages of the gas tube are twofold. The first is that the performance of the gas tube degrades with every strike. This is because each time the GDT fires, its electrodes become contaminated with carbon. This contamination will then increase the firing voltage of the device, until eventually the contamination becomes so great that the carbon prohibits the device from firing at all.

The second disadvantage of the gas tube is that it allows enormous voltage overshoot due to the time required to ionize the inert gas. This overshoot can be as much as 1200 V for a 230-V-rated gas tube, which can damage the components that the engineer is trying to protect. For this reason, gas tubes are often disregarded for board level use, and are primarily used for harsh outdoor applications.

METAL OXIDE VARISTORS

Metal oxide varistors are fabricated from various sintered metal oxides, primarily zinc, and act as non-linear resistive varying devices. Simply put, when exposed to a voltage greater than the rating of the device, the varistor's resistance changes asymptotically, allowing the MOV to absorb the transient energy. Once this voltage is removed, the MOV will return to its state of high resistance.

One advantage of using a MOV is that since its electrical properties are determined by its physical dimensions, one can obtain a very robust device. In fact a 20-mm disc can withstand a one-time pulse of up to 6.5 kA on an 8 x 20 msec waveform. Another advantage of using a MOV is that because it is a clamping device as opposed to a crowbarring device, a MOV can be used across an ac line.

Unfortunately though, these same advantages also prove to be responsible for the MOV's disadvantages. Because the MOV's performance is determined by its size, anything less than a 14-mm disc is virtually ineffective. One also needs to realize that as a clamping device, the MOV must absorb a tremendous amount of energy which breaks down the crystalline structure of the device, causing the MOV to fatigue. As the MOV fatigues, its performance degrades until the device ultimately fails. This, coupled with the slow response time of the device, prevents the MOV from being able to protect sensitive electronics.

AVALANCHE DIODES

Avalanche diodes are essentially back-to-back zener diodes that limit the voltage across a component by clamping a transient voltage after the stand-off voltage is exceeded. Much like a MOV, the avalanche diode is limited by the amount of energy it absorbs while clamping transients. But unlike a MOV, the avalanche diode does not have the same surface area. For this reason, the avalanche diode is typically restricted to low voltage applications in order to limit the heat that the silicon must dissipate.

Two of the greatest benefits of using an avalanche diode are its speed and repeatability. Because the device is made of silicon, the avalanche diode is much faster than a MOV or a GDT, and its performance will never degrade unless stressed beyond its power rating. The restriction one runs into when using an avalanche diode is that the device is both voltage- and current-dependent. Hence, as the requirements of the clamping voltage increase, the requirements of the current capability must decrease. For example, for a 1500-W device with a clamping voltage of 25 V, the current rating is 60 A on a 10 x 1000 μs waveform, whereas a 100-V device has a current rating of only 15 A on a 10 x 1000 μs waveform.

THYRISTORS

Other semiconductors used for overvoltage protection in the telecom industry are derived from thyristor technology. In principle, these solid state devices operate like a gas discharge tube, i.e., as a crowbar/foldback device. In the standby mode, the thyristor gives the appearance of being an open due to its high resistance. Upon application of a voltage exceeding the breakover voltage of the device, the thyristor will crowbar to a low resistive state, simulating a short. The thyristor will stay in this mode until the current is either interrupted or drops below the minimum holding current of the device. Once this occurs, the thyristor resets itself.

The two greatest advantages of using a solid-state device are its speed and reliability. Unlike other technologies, the thyristor permits virtually zero voltage overshoot. This means that an engineer can protect a 300-V component and still pass FCC's 268 V ringing requirement. Another advantage of using a thyristor is that the device does not fatigue, so its performance will never degrade. This, coupled with the fact that a small package can repeatedly withstand up to 500 A, makes for a good telecom solution.

The disadvantage of a thyristor is that because it is a crowbarring device, it cannot be used across the ac line. And, because it is a crowbarring device, the engineer needs to ensure that the source current is less than the semiconductor's holding current (which is typically 200 mA), or the device will never turn off.

REGULATORY REQUIREMENTS

Once the design engineer decides which technology to use, familiarity with the appropriate regulatory requirements is necessary. In the United States, the three most common are FCC Part 68, UL 1459, and Bellcore 1089 (Table 1).

FCC Part 68 applies to all telecom equipment which is to be connected to the public network. Part 68 was instituted after the divestiture of AT&T in order to protect the telecom network from being damaged. Among other requirements, FCC Part 68 tests ensure that the telecom equipment does not suppress the 268.5 Vdc ringer equivalent, that the leakage current of the protection device does not simulate an off-hook condition, and that after a simulated lightning surge, telecommunications equipment does not seize the network's line.

Unlike FCC Part 68, which was instituted to protect the network, UL 1459 was developed to protect the consumer. UL 1459 simulates

Continued on page 243

UL 1459

TEST	VOLTAGE (V_{RMS})	CURRENT (A_{RMS})	DURATION
M-1,L-1	600	40	1.5 sec
M-2,L-2	600	7	5.0 sec
M-3,L-3	600	2.2	30 min
M-4,L-4	200	2.2	30 min
L-5	120	25	30 min

L = longitudinal
M = metallic
M-3,L-3 / M-4, and L-4 — Conducted with short circuit current set at 130% value of current limiting device with current limiting device removed.
M-4,L-4 — Voltage set just below breakdown voltage of overvoltage protection.

FCC Part 68

TEST	VOLTAGE V_{PK}	CURRENT A_{PK}	WAVEFORM μsec	REPETITIONS Each Polarity
METALLIC	± 800V	100A	10 x 560	2
LONGITUDINAL	± 1500V	200A	10 x 160	2

BELLCORE 1089

TEST	VOLTAGE V_{PK}	CURRENT A_{PK}	WAVEFORM μsec	REPETITIONS Each Polarity
1	± 600	100	10 x 1000	25
2	± 1000	100	10 x 360	25
3	± 1000	100	10 x 1000	25
4	± 2500	500	2 x 10	10
5	± 1000	25	10 x 360	5

Table 1. *Regulatory Requirements.*

ALTERNATIVES FOR OVERVOLTAGE PROTECTION . . .
Continued from page 134

the safety standards for telecom equipment intended to be connected to the network, and which has an operating voltage-to-ground that does not exceed 200 Vp and 300 Vpp as set by Article 800 of the National Electrical Code. The important thing to be aware of regarding UL 1459 is that there must be some type of current limiting device, which is recommended not to exceed the equivalent of a 1.25-A slow blow fuse.

Bellcore 1089 is similar to but more rigorous than a combination of UL 1459 and FCC Part 68 in that it consists of a power cross test comparable to UL 1459, and a lightning immunity test comparable to FCC Part 68. A standard for telecom equipment being sold to the Regional Bell Operating Companies, Bellcore 1089 is mandated by the customer, not the government.

CONCLUSION

The design engineer has many choices when protecting electronic equipment. In order to narrow the search, the engineer should first determine what is to be accomplished. If quality and performance at an effective price are most important, then thyristors should be considered. If high surge current capabilities (greater than 500 A) are required, then a MOV or gas discharge tube might be most suitable. And finally, if a low voltage solution is necessary (8 V or less) then the avalanche diode will probably be the best choice.

WADE GILES received his B.S. in Physics from San Diego State University in 1988. He joined Teccor in 1992 and currently holds the position of Telecommunications Engineer. (214) 580-1515.

A LOW-COST METHOD FOR SHIELDED ENCLOSURE . . .
Continued from page 200

being measured), the maximum level that can be measured will decrease. Due to increased path loss, the received signal will decrease in amplitude by a factor of 20 dB per decade of antenna separation change; i.e., increasing the separation of the antennas from 2 meters to 20 meters will reduce the maximum shielding measurement level from 100 dB to 80 dB.

Using this portable test setup with the transmitter inside the enclosure allows the operator to localize leaking joint strips, door seals, and electrical/signal penetrations. Since the 900 MHz antennas are small, they can be used on the end of a piece of coaxial cable while monitoring the detected signal level.

CONCLUSION

The importance of frequently measuring shield integrity has often been overshadowed by the cost of these measurements. This article has attempted to demonstrate that an effective figure of merit can be obtained cheaply and effectively. While not all enclosure owners are prepared to support the required components of a do-it-yourself system, an economical commercial solution is available. It should also be noted that these spot measurements are not a substitute for recertification.

***WALTER GORDON** has been actively designing EMC test and measurement equipment for the past 12 years. Formerly an electronic design engineer with the Department of Defense, Mr. Gordon joined Chesapeake Microwave in 1991 as a senior engineer. Mr. Gordon is a graduate of the North Carolina School of Science and Mathematics and holds a BSEE from North Carolina State University. He is an active Extra class Amateur Radio Operator and an instrument pilot. (717) 235-1655.*