In Search of Electrical Surges

Sudden electrical disturbances can severely damage electronic equipment in the home and in the workplace

By IVARS PETERSON

The modern home is crammed with electronic gear – personal computers, sophisticated stereo systems, telephone answering machines, video cassette recorders. Even new models of conventional appliances, such as microwave ovens, refrigerators and dishwashers, now often contain microprocessors and other electronic components. Any of this equipment can be damaged by a sudden, sharp rise in voltage that rapidly propagates along cables or power lines. Such a surge can be caused by something as extreme as a lightning strike or as seemingly innocuous as a transformer switching on or off at a substation supplying power to a neighborhood.

Although scientists and engineers have for a long time known about the potentially damaging effects of electrical surges, or transients, their concern has mounted in recent years because the use of electronic equipment in both home and business is growing rapidly. For greater efficiency, newer electronic circuits operate at faster rates and lower voltages than before, making them even more sensitive to electrical disturbances.

Furthermore, the quality of the electricity being delivered to consumers seems to be declining. Many electricity-generating plants are being run close to their limits, particularly during periods of peak power demand. In some regions, instances of flickering lights and brownouts are much more common now than a few years ago. Such momentary power fluctuations affect both households and businesses.

The damage caused by transients carried down cables and wires ranges from the minor to the devastating. "If [a transient] causes a computer to turn off momentarily or give wrong data or even lose some data, it can be annoying, possibly disruptive," says François D. Martzloff of the National Bureau of Standards (NBS) in Gaithersburg, Md. "But if [a transient] severely damages a computer, which it can do, it can be costly and have serious consequences, especially if the computer is used for something such as controlling air traffic."

In fact, although it's difficult to calculate a precise value, businesses suffer tremendous losses annually because of electrical problems, says engineer Ronald D. Standler of Pennsylvania State University in University Park. "You don't hear about a lot of these things," he says. If a bank loses all its receipts for one day at an automatic teller, it's not going to tell the newspapers about the accident. "They don't like to cause a lot of alarm," says Standler, "so they keep it quiet."

Anyone aware of the surge problem can go down to a local electronics or hardware store and buy devices advertised as capable of protecting sensitive equipment. The shopper, however, faces a bewildering array of devices, ranging from simple, inexpensive surge-protector plugs to costly black boxes capable of keeping the electrical signal in a cable smooth and even. The trouble is that many surge protective devices, whatever their cost, don't do an effective job.

"There's not a whole lot out there in the protection market that I would want to spend my money on," says Standler, who has tested many of the devices being marketed. Both he and Martzloff have gathered a number of horror stories illustrating the problem. Standler, for example, found that one device he tested had the right kind of parts but they were connected in a completely ineffective way, affording little protection. Even after several components were destroyed during testing, the device's performance remained virtually unchanged.

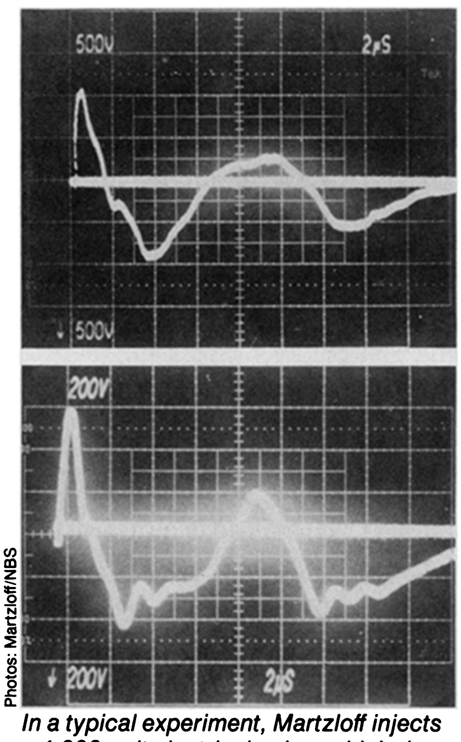
"My interest is in putting transient protection of electronic circuits and systems on a scientific basis," says Standler. "At the moment, it's a sort of witchcraft." Electrical engineers have very little guidance on how to design and use surge protectors, he says. Some circuit designers appear to do little more than to throw a few relevant parts into an electrical circuit and hope the system works.

The ideal situation, says Standler, would be to design products that include an adequate level of surge protection. In that way, consumers would not have to worry about the problem at all. But, he says, "nobody really knows how to do that."

Martzloff, who has been chasing transients for about 25 years, recently helped form a consortium of companies and organizations interested in working with NBS to identify effective ways of defending building wiring systems, communications networks and electronic equipment against electrical disturbances. "Our goal," says Martzloff, "is to recommend cost-effective ways to reduce the risk of damage done by transients."

A major part of the consortium's research program is to measure what happens to electrical surges as they charge through a building's wiring system. The types of transients in which Martzloff is most interested last only a few microseconds or less. The voltage rises steeply then falls within a short period of time.

A 10-microsecond pulse caused by cloud-to-ground lightning will be much more devastating than the nanosecond pulse generated by the opening or closing of a switch or the brief surge generated by turning on a refrigerator, a hair dryer or an electric shaver. What isn't known is over what distances these smaller tran-



Photos: Martzloff/NBS

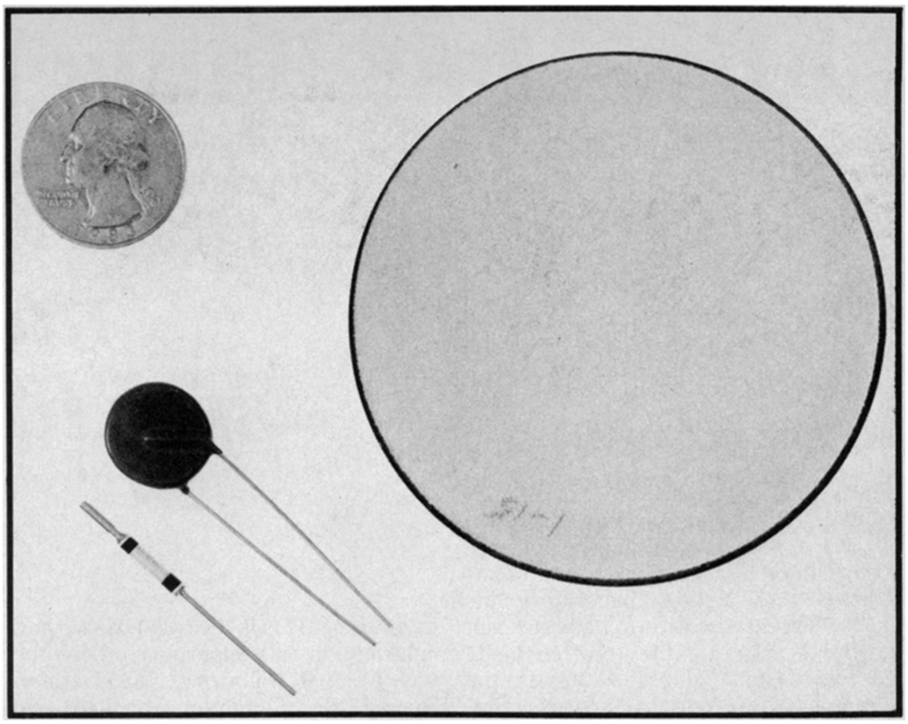
In a typical experiment, Martzloff injects a 1,000-volt electrical pulse, which rises to a peak in 0.5 microsecond, into one end of an 80-meter power cable in a building (top). At the other end of the cable, the measured pulse has a peak value of only 600 volts and carries fluctuations produced by the wiring (bottom). From such pairs of photographs, researchers hope to describe in generic terms how surges propagate along cables.

sients have an effect.

"Part of our problem is to determine how tame or how fierce the cat is," says Martzloff. "We're not as concerned if the signal starts as a tiger and arrives as a pussycat. But if a tiger goes roaring through the whole circuit, we've got potentially big problems."

Martzloff has conducted experiments at his own special, shielded laboratory at NBS and in office buildings. Typically, he injects an electrical pulse of a suitable form into one end of a cable and measures its strength in other parts of the circuit. Surges that remain strong throughout an entire circuit are the most damaging because they may harm all the electrical equipment within a building.

Standler has been monitoring electric power lines in various industrial settings. In addition, he has collected a year's worth of data on what happens within his own home, to get an idea of what kinds of electrical disturbances occur in the real world. He is also interested in developing computer models that would allow engineers to design effective surge protective devices more efficiently. "That way, I could sit at my desk to see what happens rather than having to build the device and then blast it in a high-voltage lab," he says. "It would be much less expensive and generally more convenient."



The metal-oxide varistor, or voltage-dependent resistor, is a semiconductor device often used for surge protection. A pin-mounted varistor (left) can be put into circuits carrying communications signals, while a flat-disk varistor with twin leads (middle) can be used in electronic circuits powered by 120-volt lines. A large, thin-disk varistor (right) is suitable for application in industrial power systems.

Martzloff has identified one problem, which until recently had gone unnoticed. Some types of electronic equipment, such as telephone answering machines or video cassette recorders connected to a cable network, are grounded in two different places. In the case of a telephone answering machine, the telephone wire, which carries electricity, is usually grounded near where the wire enters the house. The ground wire is often just a bare strand, one end of which is attached to some plumbing. At the same time, the machine may be plugged into an electrical outlet, which is often grounded to pipes near the house's circuit-breaker panels.

"Interestingly, multiple grounds are often set up to reduce possible surge damage," says Martzloff, "but in reality, these grounds may be ineffective or may even enhance the risk of . . . damage." In most situations, all electrical inputs that go to a given piece of equipment should have a common ground. Otherwise, an electrical disturbance, although shunted away by one grounded circuit, could induce a disturbance in a circuit grounded elsewhere, potentially causing damage. "That situation is only now becoming recognized," says Martzloff.

Other research shows that surge protective devices must be carefully matched to the electrical environment in which they are to function. The devices not only have to work effectively but also have to be in the right locations and have the right characteristics.

One type of surge protection involves the use of electrical components called varistors, or voltage-dependent resistors. These devices change their resistance in response to changes in voltage. When properly placed in a circuit, a varistor diverts strong electrical pulses away from a piece of sensitive electronic equipment. Its resistance to electrical current decreases to the point that current flows more readily through the varistor rather than through the equipment. Martzloff is studying what types of varistors work best under what circumstances.

At the moment, says Standler, "we have no performance standards whatsoever in this country for surge protective devices." Although some devices do carry a seal from the Underwriters Laboratories, that seal is geared more towards the device's safety than its performance.

However, he admits, "it's very difficult to lay down general rules about this sort of thing. There are so many different types of situations that one can run into. The general rules that work in most of these cases would be inappropriate for some of them and even cause some harm."

Nevertheless, consumers can take some precautions. Both Standler and Martzloff agree that scattering a number of surge-protector plugs throughout a house to protect individual pieces of electronic equipment is better than nothing. They recommend that a house have a lightning arrester at the fuse box or circuit-breaker panel where power lines enter the house. That device at least mitigates some of the effects of a lightning strike. Several European countries already require that kind of protection.

Standler builds his own systems, especially to protect his computers. "It's possible to make a system very reliable, and I routinely operate during thunderstorms, when lights flicker and dim," he says. But his system, which includes some components that he buys off-the-shelf, costs about $1,500 for each computer. Whether the cost is worthwhile depends very much on the value of what you are trying to protect, he says.

"Really bad transients and serious disturbances on a power line are rare," says Standler. If a person is careful and never operates electronic equipment, such as a computer, during a thunderstorm or when the lights flicker, a minimum of protection will do. "If you insist on operating when the lights are flickering or when thunderstorms are in the area, you're living dangerously unless you have protection," he says.

As one step in educating engineers and other professionals, Martzloff and Standler are preparing a book on the fundamentals of surge protection. "We want to provide some useful information for practitioners and to destroy some myths," says Martzloff, "while relieving people of unnecessary worry." □