Surge Suppressors: How Efficient Are They?

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Power-line surge suppressors must be evaluated in terms of their specific applications.

INTRODUCTION

Transient specialists realize that it takes time for a protected power supply to be charged up to the voltage level at which a metal oxide varistor (MOV) or other shunt element can conduct away surge current. If the surge is quicker than this charging time, the MOV cannot provide any protection. Thus, the essential factors which determine performance are the time it takes for the surge to charge up a power supply to the suppressed voltage level and the duration of the surge.

U.S. government standards rely on suppressed voltage as the primary measure of effectiveness. New standards call for three Suppressed Voltage Ratings (SVR), Class 1, Class 2 and Class 3.

A study of power-line surge suppressors was made to determine the relative importance of the SVR Classifications[1] for protecting switch-mode power supplies. The report raises serious questions concerning the criteria presently used to evaluate power-line surge suppressors for specific applications such as protecting switch-mode power supplies. (Most electronic equipment being manufactured today uses switch-mode power supplies).

Unlike older linear power supplies, switch-mode power supplies offer a very low impedance to the peak of the power wave, creating harmonic problems and overheating on neutral wires in otherwise balanced systems. It is this property of offering a low impedance to the power wave peak voltage that makes a low SVR so important for protecting these supplies.

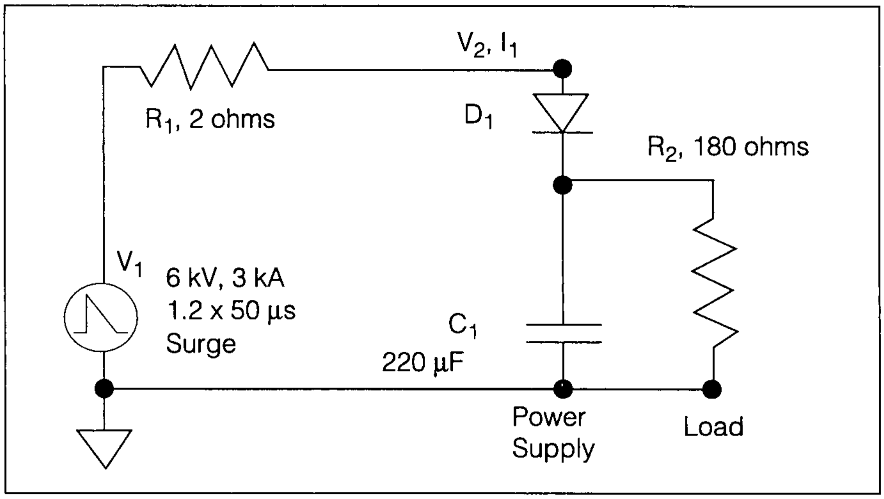

Figure 1. *Surge Applied to Unprotected Switch-mode Power Supply.*

After one understands the problem described here, it will become obvious that new test procedures and new performance criteria must be developed. These new test procedures must account for the type of load to be protected. Also, testing should be standardized by a recognized independent authority so that useful performance comparisons are possible.

UNPROTECTED POWER SUPPLY MODEL

To establish a performance reference, the industry standard 6,000-V, 3,000-A surge[2] is shown being applied to an unprotected switch-mode power supply (Figure 1).

The surge voltage and voltage developed across the power supply due to the surge current are also shown (Figure 2). Note the slow build-up of voltage across the power supply filter capacitor, C_1. This is critical to understanding the seriousness of the problem.

The results of the study cited above indicate that the voltage across the power supply rises to about 800 V due to the surge current charging the power supply capacitor. This 800 V is excessive, as the surge voltage rating of typical capacitors for this application is about 300 V. The breakdown voltage of the typical diode D_1 is about 400 V, and is exceeded, necessitating some form of power supply protection.

As expected, the full available surge current of nearly 3,000 A flows into the unprotected power supply (Figure 3). The diode D_1 of a typical power supply is rated at no more than 3 A, and 3,000 A is likely to be destructive to either the capacitor or the diode or to both.

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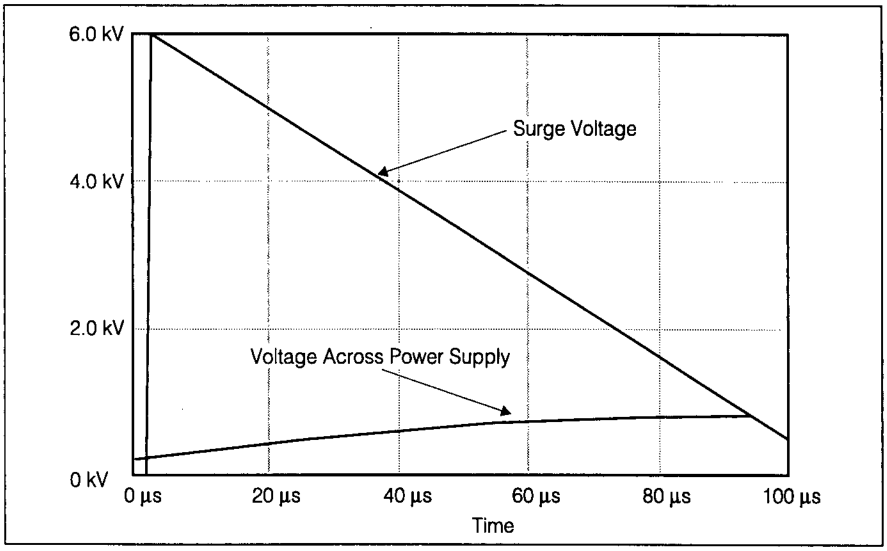

Figure 2. *Applied and Resultant Surge Voltages.*

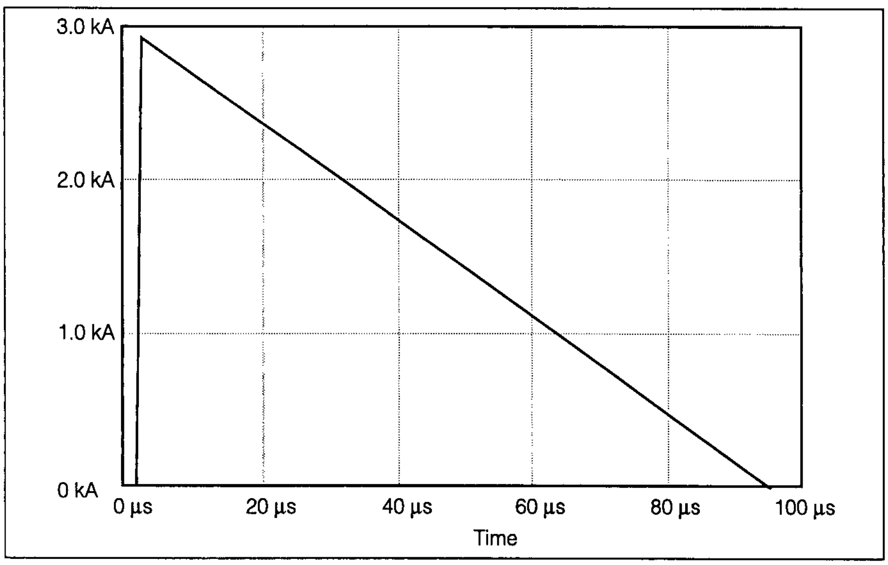

Figure 3. *Surge Current into Unprotected Power Supply.*

SHUNT PROTECTION, LARGE SURGE

The circuit of Figure 4, which includes a model for a typical 150-Vac MOV, is then evaluated. The MOV model assumes a 240-V clamp level at 1 mA of current, a 395-V clamp level at 100 A, and a 600-V clamp level at 3,000 A. These are design values taken from a manufacturer's data sheet for 20-mm MOVs. The most commonly used MOVs, 14-mm MOVs, perform much worse than this.

The surge voltage is effectively suppressed to about 500 V for the 6,000-V, 3,000-A surge (Figure 5). Thus far, the protection seems to be working. But then the devastating problem begins: all the available surge current, nearly 3,000 A, flows into the "protected" power supply (Figure 6).

Surge current continues to flow into the power supply until the power supply voltage rise (caused by the dangerous surge current flowing into the power supply) reaches the level where the MOV starts working. The MOV is subjected to only about 1,400-A surge current. Since MOVs are damaged by current, the power supply is essentially protecting the MOV during much of the surge, and nearly 3,000 A flows into the power supply, not the MOV.

While field reports indicate that the simple shunt suppressor approach does not seem to be very effective, this is the first analysis which clearly shows the theoretical reasons for the poor performance reported, how serious the problem can be, and the importance of low SVR ratings.

Based on this analysis, it can be seen that the protection afforded by the simple shunt mode approach using MOVs or other simple shunt elements is questionable in protecting modern electronic equipment. Worse yet, by diverting some of the surge current to the ground wire when the shunt circuitry is working, the technology puts audio, video and data ports, and motherboards of interconnected circuits at risk. In other words, this shunt technology conceivably does more harm than good. This fact is acknowledged by a manufacturer of surge suppressors.[3]

At smaller surges, such as the 1200-V, 600-A surge given in Figures 7 and 8, the analysis shows that the protection afforded is even less, since it takes such a long time for the power supply to charge up to the clamp level of the MOV that the surge is over before the MOV can assist.

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ADDITIONAL CRITERIA

In light of this information, it becomes obvious that additional test criteria must be developed to adequately characterize the performance qualities needed to protect nonlinear loads such as switch-mode power supplies. Present suppressor evaluations focus mainly on suppressed voltage, but the following changes seem warranted.

- A test circuit for a surge suppressor must include a load of the actual type to be protected. This is due to the nonlinear nature of some loads.
- The sample load should use components which offer impedances typical of the load to be protected, but have surge ratings that would permit them to function repeatedly in a test environment (diodes with higher amperage and voltage ratings than normal, for instance).
- The peak surge current sent directly to the protected load (bypassing the surge protection circuit), as well as the peak voltage and energy absorbed by the protected load, should be measured and recorded. In the case of a switch-mode power supply, this is quite easily accomplished. What is needed is a set of realistic standards, so that meaningful and reproducible comparisons can be made.

Until a more relevant test criteria is established, how can one select the best protection for your equipment? The U.S. government, in concert with UL, has established new performance verification testing for surge suppressors which can help ensure the most effective protection available today. This performance testing has been available to manufacturers for over a year. Grade A, Class 1, Mode 1 products are available that have passed the highest industry performance standards. Based on the preceding analysis, only Class 1 prod-

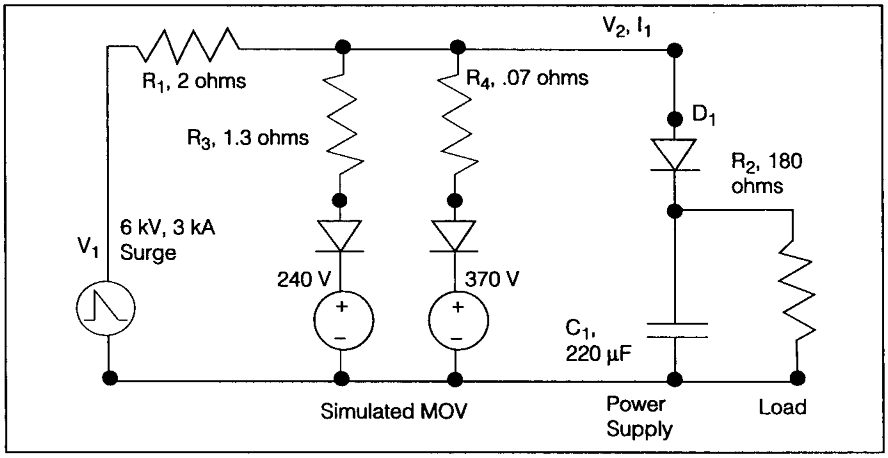

Figure 4. *Test Current Incorporating MOV.*

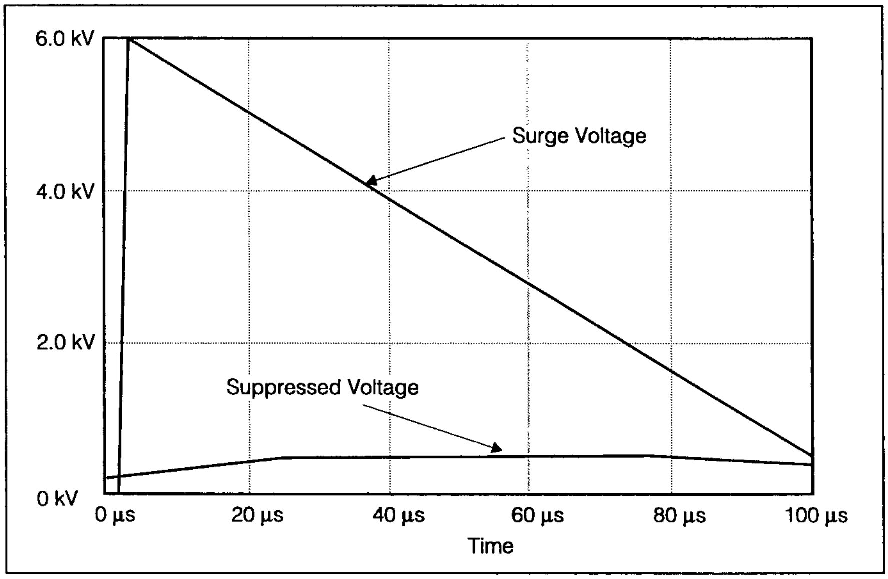

Figure 5. *Applied and Suppressed Voltage.*

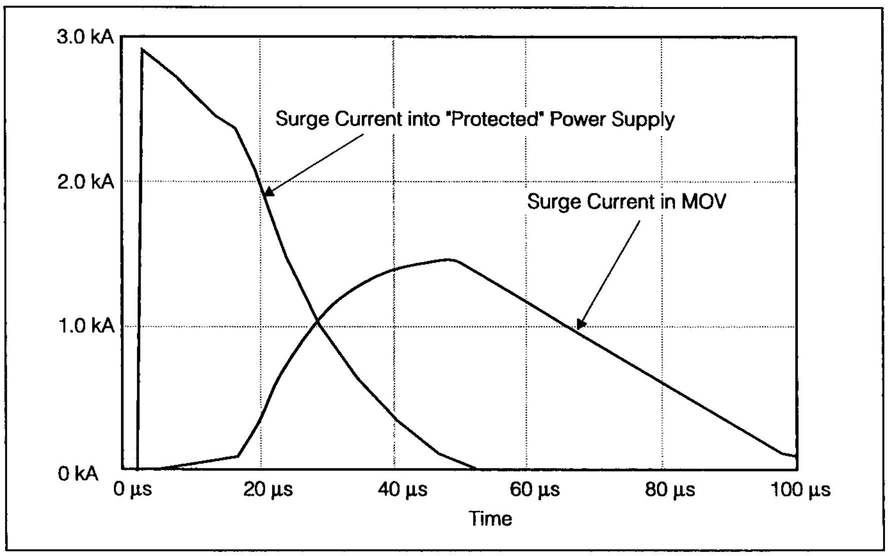

Figure 6. *Surge Current in MOV and Power Supply.*

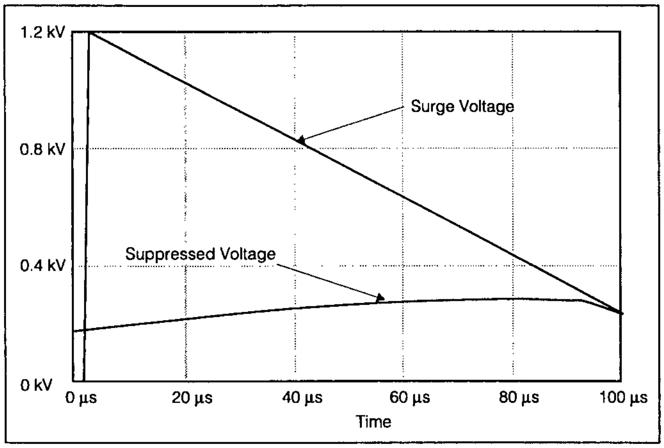

Figure 7. *1200-V Surge and Suppressed Voltage.*

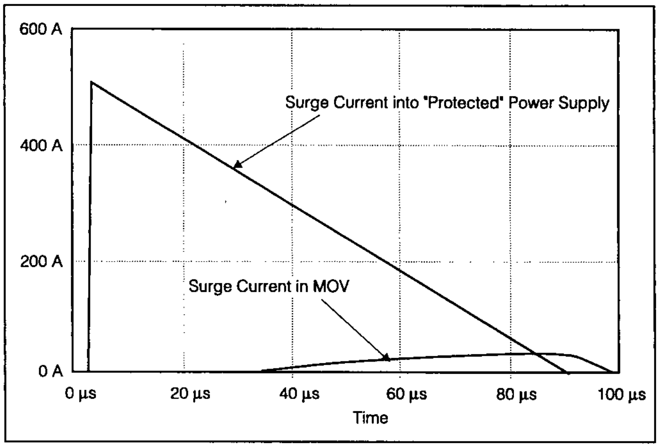

Figure 8. *Surge Currents for Small Surges.*

ucts should be considered for protecting products using switch-mode power supplies.

SUMMARY

While MOV and other shunt elements can be reliable in conducting surge currents away from linear power supplies, their usefulness for switch-mode power supplies must be carefully evaluated. Investigations reveal that simple shunt approaches must be evaluated based on the type of load being protected. New specifications to address this problem should be developed.

REFERENCES

1. US Government CID (Commercial Item Description) Number A-A-55818 dated 9 July 1996, titled "Surge Suppressor, Transient Voltage," available from Naval Publication Center, Phila. PA, FAX: 215-697-1462.

2. ANSI C62.41-1991 Combination Wave Voltage Waveform, document available from IEEE (908)981-0060, Piscataway, NJ.

3. APC technical note #T3, dated 8/91, available from American Power Conversion Corp. (401)789-5735.

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