SURGE TESTING OF LOW POWER AC CIRCUITS

The transition from relay logic to discrete transistor logic, to today's complex LSI integrated circuits has been accompanied by a much greater potential for equipment malfunctions and damage due to voltage and current surges. Voltage or current surges, defined here as a spike transient of some nature, have been carefully observed over the past ten to fifteen years, both in the laboratory and in the field, and lead to some definitive ideas about the characteristics of the surges. See Figure 1.

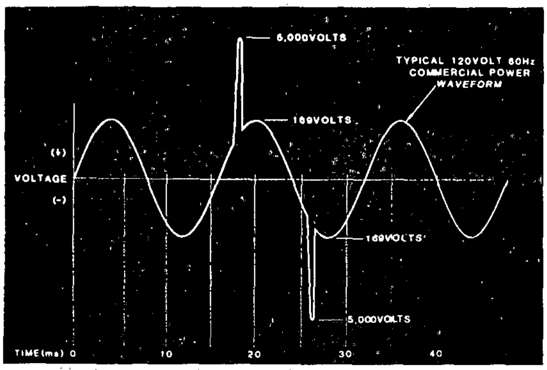

Figure 1. Typical Transient before clamping.

Since power surges are found at some point in almost all ground-based electronic systems, the problem of protecting this equipment from the damaging effects of these surges is an essential part of the design verification and manufacturing test procedure for these products. This growing awareness of the nature and cause of random failures in systems subjected to power line surges has prompted a drive to develop standardized test methods and test equipment with which to conduct design verification and product test acceptance. Recent experience in the laboratory and in field observation has indicated that spikes as high as 2 to 6kV indoors and 10 - 20kV outdoors are commonly found in most geographic areas of the United States.

Surges on the power line may originate from many sources. Typical sources are system switching transients, electrostatic discharge and indirect lightning effects. For example, energizing and de-energizing transformer primary windings may create transients greater than 10 times the voltage being switched upon de-energizing the transformer primaries. Energizing and de-energizing inductive devices such as solenoids and auxiliary coils, or switch and circuit-breaker arcing are among typical events creating power surge transients. Lightning strikes, both on primary and secondary circuits and coupled into smoke alarm or burglar alarm loops, and other indoor wiring lines can create transients thousands of volts in amplitude and thousands of amperes in current capacity.

Surge protection is difficult to specify due to the variability of surges encountered at different locations and with various types of circuits, but suppressor techniques have developed through the years. These include the use of gas tubes, which provide controlled breakdown, and may consist of two or more elements that can provide protection for multiple circuits. The firing point of these gas tubes is a function of the slope of the wave, and this, plus the need to provide extinguishing capability in the circuit, commonly make them good only for slow rise time surges.

Metal Oxide Varistors, or MOV's, absorb the transient energy instead of reflecting it, and are quite fast. They do not have a sensitivity to the rise time of the surge, and also exhibit a predictable firing point. Silicon avalanche suppressors, which are essentially large junction zener diodes, provide super fast (low nanosecond response) and wide voltage range capability. These are ideal for protecting logic circuits. Hybrid protectors, consisting of combinations of these devices are often used also.

Two IEEE guides are presently in use for specifying test waveforms and test methods for surge testing. These are IEEE-STD-472-1974 and IEEE-STD-587-1980. These two guides are complementary, and each provides for waveform and test methods applicable to a wide range of products.

IEEE-STD-472-1974 specifies a test waveform consisting of a 1 to 1.5 MHz frequency oscillatory or ring wave which exhibits a very fast initial rise time and a specified envelope decay time. A typical test waveform is characterized by a 1.25 MHz frequency, with a very fast initial rise time, 100ns(4c), provided by a cosine wave with an envelope decay time to 50% of the initial amplitude in 6 microseconds. See Figure 2. The pulse amplitude is specified at 2.5-3kV with a source impedance of 150 ohms.

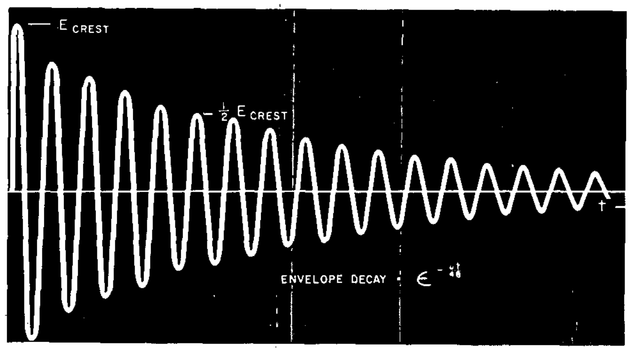

Figure 2. Surge Withstand Test Waveform (only one burst is shown).

IEEE-STD-587-1980 specifies two principal categories of test waveforms. Category A defines an oscillatory or ring wave which oscillates at a basic 100 kHz rate, and requires an 0.5 microsecond rise time. The specification further defines this waveform such that each successive peak amplitude shall be 60% of the preceding peak, which gives rise to the waveform shown. Current requirement, on this category A signal, is 200 amps into a short circuit with a 6kV signal amplitude into an open circuit. See Figure 3. Category B requires two unidirectional impulse waveforms. The first is a unidirectional voltage waveform, consisting of a 1.2 μ SEC rise time and 50 μ SEC fall time (50% point) waveform, which will produce up to 6000 volts into a high impedance load (open circuit voltage). See Figure 4. The second unidirectional waveform is an 8 μ SEC

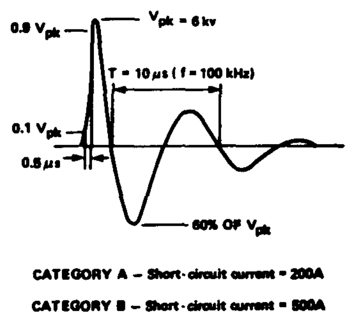

Figure 3. 0.5 μs ~ 100 kHz Ring Wave for categories A and B.

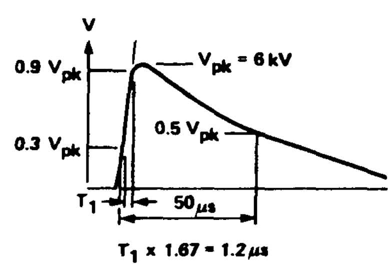

Figure 4. Theoretical Classic Power-line Impulse Voltage wave, usually 1.2×50.

rise by 20 μSEC fall signal, which can produce up to 3000 amps into a low impedance load (short circuit current). See Figure 5.

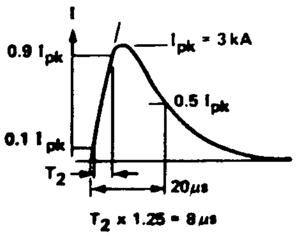

Figure 5. Classic Power-line Impulse Current wave, usually 8×20.

In addition, for category B tests, the 100 k Hz oscillatory wave of category A requires 500 amps current into a low impedance load (short circuit current). The rate of surge occurrence vs. voltage level may be found in various unprotected locations. See Figure 6. The low exposure location defines systems in geographical areas known for low lightning activity and light switching activity. Medium exposure areas are those with systems used in geographical areas known for high lightning activity with frequent and severe switching transients. High exposure areas are rare, and are not commonly used as a test requirement.

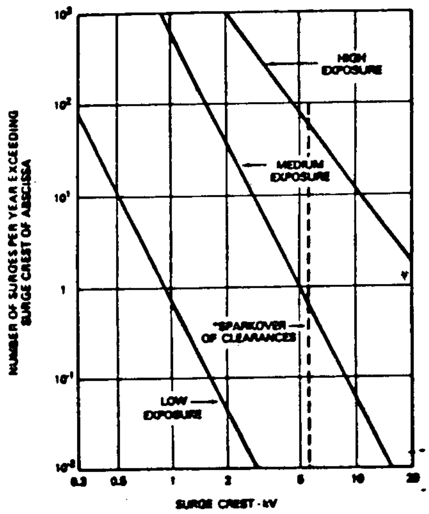

Figure 6. Rate of Surge Occurrences vs. Voltage Level at unprotected locations.

2-3 kV amplitude covers requirements in low to medium exposure areas occurring from once every 10 years in a low exposure area, to several times per year in a medium exposure area. When 5-6 kV is reached, these voltages typically do not occur in low exposure areas, and occur perhaps once every one or two years in medium exposure areas.

It should be noted that timing the application of the surge transients is important. Surges due to natural phenomenon occur at random times with respect to the power frequency. A means is required to synchronize the surge with the power frequency and a phase control which allows the position of the transient in time with respect to the incoming AC wave form to be adjusted for any position of the surge from 0 to 180 degrees.

In addition, external triggering is desirable to position the surge in time with respect to an external phenomenon. For example, if a test is to be conducted wherein the surge is to be applied to the equipment under test during some specific operation, this external triggering capability permits the timing of the point of surge application in relation to operation of the equipment under test. This is important, in that the failure mode of these devices may be affected not only by the surge, but by the power follow current. This is defined as the amount of current drawn by the equipment under test, following a breakdown due to the application of the surge. Since the surge is very narrow in pulse width, it is often true that the power follow current actually does the major damage. Therefore, timing of the surge with respect to the power frequency affects the level where the failure occurs. This would also indicate that surge testing should be done with line voltage applied to the device under test.

Although radiated-field and flux-coupled surge testing are possible, surge testing is normally done utilizing conductive coupling. Two methods of conductive coupling are used: common and transverse (normal) mode. Common mode connection (also called longitudinal mode in telecom usage) defines a means of surging whereby one side of the device under test is connected to ground (common). Transverse (normal) mode is defined as the method of coupling between two lines such as hi and low or hot and neutral power lines. This is also called metallic coupling, since only metal lines are coupled, not earth (ground) as defined in old telecom usage.

A surge test plan should normally include testing with surges of both polarities, including common mode testing between neutral and ground (which is typically the worst case) and should include a full scale passive test first, with power-on test second. As indicated previously, phase control of the surge position should include testing with the surge position at various locations from 0 - 180 degrees of the power frequency.

Isolation networks (also called surge couplers) present several problems. First, typical load currents for the device under test may be 10 - 20 amps RMS, and in some cases higher values are used. The use of high peak surge voltages, 2-6 kV, and the requirement to produce extremely high surge currents through the load, combined with the wide pulses typically used, present serious problems for the designer of the isolation network. The range of power line frequency used can be from DC to 400 Hz and their period can be close in value to the equivalent surge period under certain conditions. In addition, the filter should have a very small line voltage drop, but at the same time must provide for a large attenuation of surge voltage. Other items such as limitation of the line inrush current, providing adequate safety protection, and reasonably sized packaging, with human engineering for ease of operation, and, of course, low cost are all factors that have to be considered.

Surge monitoring is a valuable and necessary tool in surge testing. All generators should provide the capability for a scope monitor output with trigger which permits viewing the generated waveform (reduced 1000 to 1 and referenced to ground) on a standard oscilloscope with the oscilloscope trigger permitting easy synchronization of the waveform for viewing.

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