TRANSIENT CONSIDERATIONS FOR CATV SYSTEMS

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ABSTRACT

This paper deals with the damage and outages caused by both natural and man generated transients which are a major, very costly problem for CATV system operators. The paper is divided into 3 categories:

1. The nature of transients
2. Source of transients
3. The prevention of damage and outages from transients

The emphasis in the paper involves an analysis of how transients get into the cable systems. These are categorized in such a manner as to enable analysis and preventative measures to be taken.

Protective devices are discussed in some detail including the characteristics and limitations of these devices. The major solution discussed in regard to preventing transient damage is the grounding system as used conventionally and as it might be used to improve the grounding action. The solutions discussed in the paper have been based on experience of systems as observed over the past two years.

INTRODUCTION

Damage and outages caused by transients are a major and very costly problem for CATV systems especially for those located in areas of high transient activity.

The problems created include those caused by any system outage; the main ones being customer complaints and dissatisfaction; the added time and expense of maintenance crews.

In addition, a considerable amount of equipment damage can occur. RF transistors by their nature are very susceptible to damage. To a lesser extent, power supplies, splitters, directional couplers, filters and power chokes can be damaged by transients.

For purposes of discussion, we can separate the subject into the following categories:

1. Nature of transients
2. Source of transients
3. Prevention of damage and outages from transients

THE NATURE OF TRANSIENTS

The damage caused by transients can be appreciated if we look at the nature of transients, i.e., rise time, duration and particularly the magnitude of the currents and voltages.

Direct lightning strikes have had the following recorded:

Current:	10,000 amps avg. to 260,000 amps maximum
Rise time:	12,000 V/usec
Voltage:	72,000 V
Waveform Definition:	6 x 20 is a standard test waveform for typical lightning strikes

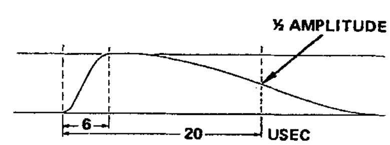


Figure 1

The first number is the rise time, the second is the time to decay to 1/2 amplitude.

Power line surges resulting from load switching transients can range from one usec to the larger part of a second. Currents of 2000 amps and voltages of 15,000 volts are not uncommon.

Higher and lower values for transients can be cited, however, when compared to the 24 volt transistors we use, the magnitudes are formidable.

THE SOURCE OF TRANSIENTS

We can classify transients into two types.

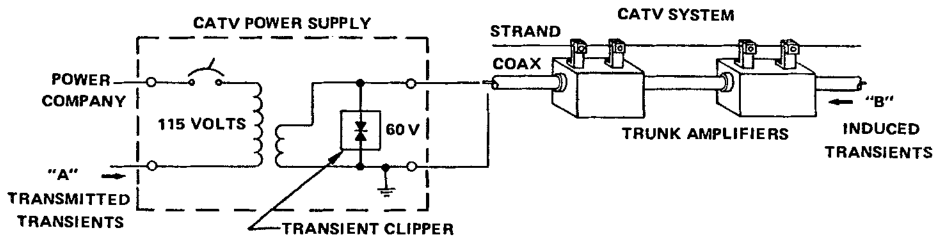


Figure 2

A. Those which enter the system via the 60 Hz pole mounted A. C. power supplies. These transients are present on the power line and enter through the 115 volt primary. These power surges are usually present where heavy industrial loads are being switched. Automatic reclosure of power company circuit breakers also create transients to the power supply. Lightning can also be a cause. It is interesting to note that power interruption for less than 5 seconds is not classified as an outage by many power companies. In a typical power company, there may be 2,500 per year of these short duration nonclassified outages which cause transients.

Ferro-resonant type power supplies due to their nature can cause a transient as high as three times rated output voltage when turned on.

Protection for these transmitted type transients can be provided by several types of devices.

B. The other type transients are those which are inductively coupled into the strand or coaxial sheath of the CATV system. These may be caused by power line faults, load switching, lightning and atmospheric effects.

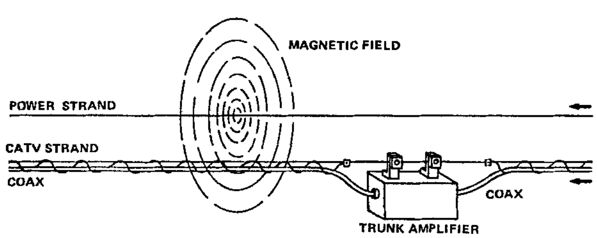


Figure 3

Inductive coupling shown in Figure 3 occurs due to current in a conductor (such as the power strand) creating a magnetic field which cuts (or couples) another conductor (in this case the CATV strand). A voltage is generated in the CATV strand which will cause a current to flow. These currents in both the power and CATV strand flow to the best ground point or points.

Both transients and steady state voltages can be inductively coupled when neutral (strand) or unbalanced currents flow in parallel conductors.

The most important consideration for system protection from this type of transient is a good grounding system.

PREVENTION OF DAMAGES AND OUTAGES FROM TRANSIENTS

Theory is interesting but most important, what are the practical methods a system operator can use to protect his system against transient outages.

Protection for those transients entering from the A. C. power supply is relatively simple. The Transient Clipper, used and field tested by Theta-Com, has proven to be quite effective.

Let us look at how the Transient Clipper protects the system from transients which enter through the power supply.

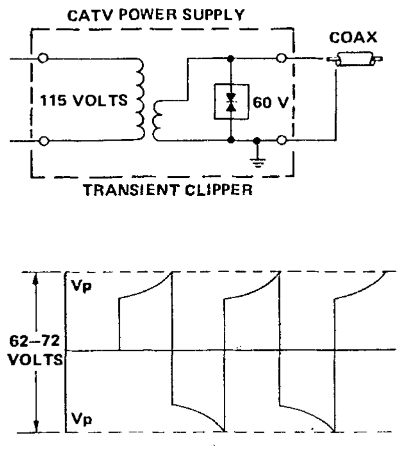


Figure 4

The typical waveform from a ferro-resonant supply is shown in Figure 4. The peak value is 62 to 72 volts at full load and no load respectively. The Transient Clipper is connected across the 60 volt (RMS.) terminals and will conduct when the peak voltage exceeds 91± 10% in either a positive or negative direction. This is done by a network of avalanche (zener) diodes. The voltage and current characteristics of the transient clipper and three other devices are shown in Figure 5.

Ferro-resonant type power supplies (which are used by the majority of CATV systems) produce a voltage transient of 2 to 3 times rated voltage when turned on. This will decay to normal in 2 or 3 cycles of the 60 Hz frequency. The Transient Clipper will clamp these at a lower voltage than the spark gap type devices. The spark gap units at times would not turn off due to the power supply short circuit current. When they do not turn off, they will destroy themselves by melting solder joints in the associated circuitry. The Transient Clipper does not have this problem as it turns off at approximately 91 volts peak.

The basic circuit device in the Transient Clipper has been used in airborne electronics equipment to protect voltage sensitive components from large voltage transients. The device was tested in the Theta-Com Engineering laboratory and subsequently installed in several systems that were experiencing severe transient problems.

The resulting reduction in transient damage and outages has been dramatic in most cases.

Time delay relays which allow time for transients to pass before connecting power to the cable system have been used with good results. The Transient Clipper will perform the same function and operates much faster.

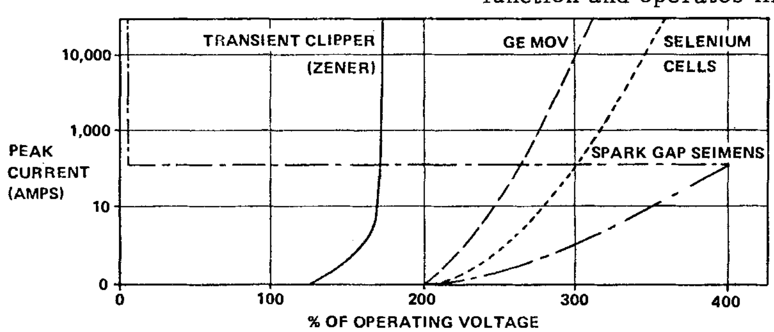


Figure 5

Characteristics of The Transient Clipper

The sharp curve (zener characteristic) allows the breakdown voltage to be set reasonably close (130%) to the operating voltage. Other devices used start at 200% and some go to 400% voltage before complete breakdown. When the Transient Clipper conducts, it clips above 91 volts but does not present a low impedance or short circuit as does the spark gap device. The turn on and off time is very fast at 10^{-12} seconds (one millionth of one microsecond). It has a peak pulse power dissipation rating of 15,000 watts and a peak pulse current rating of 300 amps. The small size of the Transient Clipper allows it to be easily mounted in the power supply housing.

Protective devices such as fuses, surge suppressors, transient clippers, over-voltage circuits are necessary and useful to protect equipment, but, they many times create a secondary problem by causing a system outage in the process.

Protection against type B(see Fig. 2) transients which enter from the strand is more difficult. The most important element for protection is a good grounding system. The grounding system should minimize the magnitude of the transients before they reach the equipment and protective devices. This will reduce the fuse type outages to a necessary minimum.

General Ground System Considerations

The resistance should be as low as possible. Wetter soil and higher clay content will have lower resistance. OSHA requires 8' ground rods. Multiple ground rods can be used to provide a lower resistance.

In addition to resistance, the inductance of the ground lead is a factor. A high inductance will produce a high transient voltage. Lower inductance can be provided by multiple leads, woven copper straps are also quite effective.

Antenna Site

1. The mast should be higher (preferably 10') than the antenna.
2. Heavy copper conductors should run from the top of the mast to the ground system instead of depending upon the mast for conduction.

In extremely dry soil, a good ground is difficult to establish. Methods that have been used are: several buried radial 100-200' copper conductors, large masses of scrap metal such as car radiators have been buried 4 to 6' deep to provide a ground.

Cable Distribution System

The generally recommended considerations for good grounding should be followed.

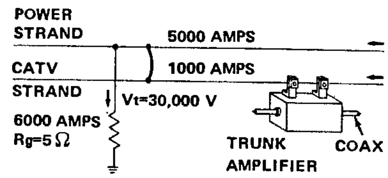
Ground resistances on the order of 5 ohms are desirable. Good grounds in dry climates may be impossible to establish.

The commonly used practice of obtaining a ground by "strapping" the CATV strand to the telephone or power company strands has in many cases created transient problems for the CATV system.

There are three grounding situations shown in the diagrams below which are significant. In all three situations it has been assumed that the surge current in the power strand is 5000 amps and a surge of 1000 amps has been inductively coupled into the CATV strand and coax sheath. A ground resistance of 5 ohms has also been assumed.

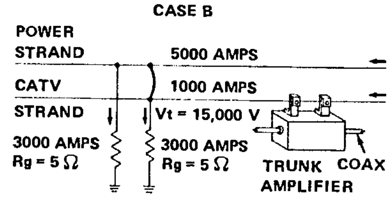
In case A shown below, the CATV strand is "strapped" to the power strand and the sum of 5000 and 1000 amps flow through the common ground resistance of 5 ohms, producing a voltage at the amplifier case of 30,000 volts.

CASE A



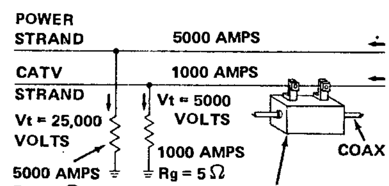
In case B shown below, a separate ground lead and rod have been installed on the CATV strand which is still strapped to the power strand. The total surge current of 6000 amps divides equally between the two grounds and produces 15,000 volts (3000 amps x 5 ohms) at the amplifier housing. This is a 2 to 1 improvement over case A.

CASE B



In case C shown below, the strap has been removed from the power strand, allowing the surge current in each strand to follow the separate grounds installed on each system. The 1000 amps in the CATV strand will produce 5000 volts (1000 amps x 5 ohms) at the amplifier housing. This is a 6 to 1 improvement over case A.

CASE C



The above is intended to illustrate the problems that can be encountered in grounding systems and the importance of low ground resistance. There are requirements, in many instances, to be strapped to power grounds. However, some systems having consistent transient problems were able to cure them only by removing the strap.

The magnitude of the currents and voltages are chosen only to illustrate the circuitry involved. Other factors such as cable resistance and inductance affect the magnitude of the transient voltage at each amplifier. Analysis of equipment damage has shown that voltage transients of over 2000 volts commonly reach the equipment.

History of Typical System Experience

1. Area of high transient activity.
2. Trunk line of 5 miles on power line poles. All poles grounded with butt plates.
3. CATV system was strapped first, last and tenth poles to power strand.
4. Transients induced voltages on CATV strand and tripped amplifier over-voltage protection which consistently blew fuses.
5. Separate grounds were installed at each amplifier and each adjacent pole. This gave significant improvement.
6. Some outages continued until straps were cut from power strand.
7. No outages for several months during last storm season.

Protective Devices

Spark Gap Surge Suppressor -

1. Used extensively directly on RF line to protect transistors. They are the only device with sufficiently low capacitance that can be used on coax center conductors without affecting the RF signals.
2. Firing time varies with transient rise time. At 500V/microsecond firing time is approximately 2 microseconds. At 100V/microsecond firing time is 5 to 10 microseconds.
3. Firing point usually 200% of rated voltage to allow device to turn off.
4. Low impedance during conduction creates transient on ferro-resonant supplies. Can create a sustained short due to continued arcing. (A 35 amp follow on current rating will prevent this).
5. Voltage across the device can rise to 400% of firing voltage during ionization and prior to arcing.
6. Specifications

Siemens P/N	Firing Volt.	Peak Surge Current
B1-C90/20	90 ± 20%	5 KA
B2-C145	145 ± 20%	5 KA

Follow On Current	Insulation Resistance	Capacitance
20A	10K	2 pf
35A	10K	1 pf

Silicon controlled rectifiers -

1. Breakdown to low impedance.
2. Are hard to turn off.

Metallic Oxide Varistors (type of selenium) protector) -

1. Fire at 200% of rated voltage.
2. Will not take surges of ferro-resonant supplies.

Transient Clipper -

1. Is a bipolar (back to back) power type avalanche or zener diode.
2. Clamps at a fixed voltage level @ 130% rated voltage.
3. Does not break down to low impedance.
4. Fast firing and fast recovery.
5. Used across secondary of system power supply.
6. Responds to peak voltage.

Fuses -

1. Protect circuit devices such as rectifiers, transformers, etc. but not transistors.
2. Slow acting. Slow blow fuses are used to prevent nuisance tripping.
3. Firing time is in the order of 1 to 5 milliseconds to 1/2 second.

Thermal Breakers (Sylvania P/N ESB710E3A) -

1. Used in bridger legs in series with fuses to prevent nuisance fuse outages due to momentary shorts during tap installation.
2. Has been used in place of fuses. Has a slightly slower firing time. Contact could weld shut. Series fuse should be used.
3. Cycling on permanent short can affect other bridger legs.

Crowbar Circuit -

Used in the amplifier D. C. power supply to sense D. C. overvoltage which may be caused by transients. Zener fires an SCR which clamps DC voltage to low level and blows DC fuse.

Thyrite Pellet Arrestor -

Used across primary of power supply to reduce transient load on primary. Basically a high current device.

Time Delay Relay -

1. Used across power supply to sense over-voltage and take power off cable system for fixed delay time and until transient has passed. 10 - 20 seconds.
2. Mechanical device.
3. Slow acting on initial transient.
4. Has proved effective.
5. Transient clipper should be more effective.

Coupling Capacitors -

1. On amplifiers, smallest capacitance value usable as a blocking capacitor will limit transients.
2. On passives, 500 volt capacitors are preferable. Actual breakdown and test voltages of capacitors are compared below:

Life Rating	Test Voltage	Actual Breakdown Voltage
200V	600V	2100
500V	1500V	2500

CONCLUSION

Transient problems vary considerably in different systems and in various parts of each system. An exact analysis is difficult due to the expensive instrumentation task which would be necessary.

An upgrading of the grounding system, use of transient clippers, surge suppressors and proper coupling capacitors should solve the majority of transient problems.