CATV Plant Protection - Part I

I. Introduction.

Cable television systems, in general, have not always placed a high priority and emphasis on outage reduction and elimination. Since the fall of 1989, the emphasis has been elevated because of consistent consumer research which points to high levels of subscriber dissatisfaction when multiple outages are experienced. A Cable Television Laboratories Committee on Outage Reduction was also formed in late 1990 to address these issues, and to develop a methodology whereby outages can be significantly reduced or eliminated in the typical cable distribution system. The information contained in this document was developed from ensuing research begun at that time with Cable Labs.

The text included in this examination will be separated into two technical reports, with the first examining protective devices themselves, and the second reviewing their proper application.

In general, the past industry approach to voltage transient/over current protection and grounding/bonding techniques can be summarized as follows: deployment of transient clipping devices such as Metal Oxide Varistors and Silicon Avalanche Diodes (Tranzorbs); plus plant grounding and bonding. If one assumes that the primary emphasis should be limiting or even eliminating transient related conditions in cable systems, an improved methodology can be developed. Proper device application, plus some discussion of grounding and bonding will be covered in Part II. For now, lets take a much closer look at "protective devices".

II. General Description of protective Devices.

General protective device categories are:

1. Over-Current sensing..
   - a)Fuses
   - b)Circuit breakers
   - c)Thermal breakers

This category of devices are intended to provide protection for equipment, personnel, and to isolate shorted conditions in a circuit or system (take a shorted section off-line while keeping the main portion of the system running). Advantages of these devices include the ability to handle large energies with negligible circuit loading. Negative characteristics include slow reaction time, eventual failure over time due to surges or mechanical problems, and a tendency to create system outages when they fail.

2. Transient Clippers [Clamping voltage transients at a certain level]..
   - a)Metal Oxide Varistors (MOV's)
   - b)Silicon Avalanche Diodes or Tranzorbs™

Transient clippers, as a group, are intended to provide protection against peak transient voltages and corresponding overcurrent conditions. The transient protector will sense the leading edge (rise time) of the voltage transient, and act to clamp the peak of the voltage waveform at some designed voltage limit, dissipating the peak power within the device itself at the junction. Strong points are their ability to respond to peak voltage conditions, fairly fast response times, and ability to handle large amounts of energy *for short durations* depending upon device ratings. Negative points are they are damaged under certain conditions or repeated surges (MOV's can be destroyed by transients from ferro-resonant transformers themselves), and a lack of indication when the device has failed.

3. Transient Shunting Devices/Circuits..
   - a)Crowbar Circuits
   - b)Spark-Gap Transient Protectors or SVP's

Transient shunting devices are intended to detect transient voltage conditions at the coax center conductor, then fire at a predetermined level shunting all voltages and currents to ground potential.

A crowbar, once fired, remains fired until the voltage is reduced to zero at which point the circuit resets. If employed in an AC circuit it will automatically reset during each half-cycle at the zero voltage crossover point; if employed in a DC circuit it will remain fired until the voltage is removed - normally through fuse failure. The crowbar circuit contains both active and passive components; while the SVP is a purely passive device. Strong points for this type of circuit/device are a fairly fast response time, the crowbar can handle very large amounts of energy since the voltage is shunted directly to ground and not dissipated in the device itself. SVP's can be placed directly across the coaxial line as they have a very low impedance (a few picofarads). Negative points for SVP's are that they may ionize under repeated transients, passing surges on to the device.

III. detailed information on protective devices.

A more detailed description of *each* device type now follows:

- Spark Gap Transient Suppressor (SVP): SVP's are used extensively by some equipment manufacturers directly on RF lines to protect circuit components. They are the only device with sufficiently low capacitance to be connected directly from coax center conductor to sheath without adversely affecting the RF signal. The clamping or firing time is dependent on the transient rise time, but typically from 1 microsecond to 10 microseconds. The firing point is usually 200% of the rated voltage.
- Fuses: Fuses are comprised of five main types: time delay, dual element, non-time delay, very fast acting, and limiters. Types in use in cable systems are typically time delay and dual element. A new type of fuse class, **communications**, is under development by

Littlefuse Company. This is a "very slow blow type", and may find good application in cable systems.

- Circuit Breakers: A mechanical device which magnetically senses overcurrent conditions, then opens a set of contacts interrupting current flow to the load.
- Thermal Breakers: An overcurrent sensing device containing a set of bi-metallic contacts through which the circuit current flows. An overcurrent condition will cause the bi-metallic strips to over heat and bend or "break" apart, thus interrupting current flow to the load. The bi-metallic strips then cool and reclose again (typically within a few seconds) depending upon device design.
- "Smart" Breakers: A thermal breaker with an accompanying heater element, all in a sealed case. Overcurrent conditions will cause the bi-metallic strips to open initially; the heater element then continues to maintain the contacts open while the shorted condition exists because short circuit current is through the heater element. Once the overcurrent condition is removed, the breaker may or may not reset itself. Sometimes, normal current flow through the device will maintain sufficient heat from the heater element to keep contacts open, thus necessitating a visit to the device, and pulling or replacing it for cool down! It is available from Sylvania in several values.
- Metal Oxide Varistors (MOV's): A transient voltage clipping device. Sometimes used on the primary side of the main AC supply, occasionally elsewhere. It is an energy absorbing, soft clamping device. Clamping speed depends upon the voltage rise time. Once fired, it continues to pass voltage through the device at the clamped level. It cannot be used where RF is present as they insert a large amount of capacitance in the circuit. They also have a limited transient life expectancy. Further, they are sensitive to, and damaged by, transients from ferro-resonant devices (main line power supplies).
- Silicon Avalanche Diodes (Tranzorb™**):** A transient voltage clipping device. Sometimes used on the AC power supply secondary side, or in amplifier power supplies for transient protection. It is a hard clamping device ie clamps at a specified threshold, and limits all voltage beyond that level. Because it dissipates the voltage transient internally, it needs external current limiting and is subject to damage by large surges. Tranzorbs have a very fast clamping speed (less than one nanosecond), and are available in a polar or bi-polar configuration.
- Crowbar Circuits (Ampclamp™/Powerclamp™): An active/passive circuit designed to fire at a designed overvoltage level, then short out or shunt the entire voltage waveform during the remaining transient period - normally one-half cycle in an AC circuit. The circuit typically employs two SCR's or a single Triac, and resets at each zero voltage crossover point in AC applications. Crowbar circuits are of three main designs: current limiting, current foldback, and power foldback. Crowbar circuits can handle large amounts of transient energy - since all energy is coupled to ground once fired and very little is dissipated within the device assuming good ground conditions. Their clamping speed is very fast, and a well designed and properly installed crowbar can be considered the primary means of transient protection in the modern cable system.

Detailed Device Data

Fuse

Type Device: Current Sensing, disconnects load from the source.
Clamping/Firing Level: Overcurrent through device
Firing Time: 5 μsec to >1 second; depends on type with 5 main types available. A "typical" fuse firing time is around .1 second.
Where Typically Used: Almost all system locations currently; main AC power supplies, equipment power supplies, current routing locations such as passives, power inserters, amp input/output, bridger legs, etc.
Characteristics:

- Purpose is to protect equipment, personnel, and to isolate short circuits.
- Protects circuit devices ie transformers, etc., ***but not semiconductors***.
- Can handle large amounts of energy, and causes negligible circuit loading under normal conditions.
- Slow reaction time because they react to temperature change in an overcurrent condition. Slow blow, time delay, and over-valued fuses can be used to prevent nuisance tripping.
- Fuses age/weaken over time due to transients or overcurrent, eventually will cause a nuisance outage even under normal system conditions.

Recommended Use: Recommended use is limited; primary of line equipment power supplies, secondary of main AC supplies as total current limiters, and for the isolation of distribution legs (AC routing points in trunk) from short circuit conditions. Values must be chosen carefully to prevent nuisance fuse tripping with resulting outages. Repeated fuse blowing at a given location may indicate the presence of other problems such as longitudinal sheath current conditions.

Mechanical Circuit Breaker

Type Device: Current sensing, typically through magnetic coupling, which disconnects the load voltage from the source.
Clamping/Firing Level: Depends on the overload condition- examples:
110% of rating = indefinitely
150% of rating = approx. 60 seconds
200% of rating = approx. 20 seconds
300% of rating = approx. 5 seconds
Firing Time: > 1 second, see above.
Where Typically Used: Typical applications are in main AC power supplies on the primary side.
Characteristics:

- Operates indefinitely at rated current.
- Mechanical device, and is inherently less reliable.
- Very slow acting compared to other devices.

Recommended Use: Input to main AC supply as an AC disconnect only.

Thermal Breaker

Type Device: Current sensing, disconnects load from the source.
Clamping/Firing Level: Depends on overload condition.
Firing Time: >1 second typical.
Where Typically Used: Sometimes used in bridger legs, power inserters, passives, etc.
Characteristics:

- Simple in design and concept.
- No nuisance fuse blowing.
- Slower acting than a fuse.
- A cycling thermal breaker may "fuse" its contacts under repeated short circuit conditions.
- Can cycle on a permanent short, which can take down (short) other bridger legs **and the trunk**!
- The device is temperature sensitive <u>ie</u> the amount of current required to trip is greater at lower temperatures.
- Overall accuracy and stability of the device is questionable.

<u>Recommended Use:</u> General use not recommended in cable systems at this time.

Smart Breaker
<u>Type Device:</u> Current sensing, disconnects load from the source. A heater element keeps the bi-metallic thermal breaker contacts open during the remainder of an overcurrent condition. Unit is encased for increased reliability. Normal circuit current can keep the unit activated once the short circuit has cleared, thus the unit may require replacement or cool-down once triggered.
<u>Clamping/Firing Level:</u> Depends on overload condition.
<u>Firing Time:</u> >1 second typical.
<u>Where Typically Used:</u> Relatively new for CATV application, typically distribution leg fusing or power inserters.
<u>Characteristics:</u>

- Simple in design and concept.
- No nuisance fuse blowing.
- Slower acting than a fuse.
- Will <u>not</u> cycle on a permanent short due to the heater element.
- Some temperature sensitivity which can affect accuracy.
- Unit may have to be pulled for cool-down and resetting under some system/circuit conditions.
- **Much** more expensive than a fuse.
- Some "drawbacks" may be unknown due to limited application in current CATV plants.

<u>Recommended Use:</u> Device would seem to be a good candidate for use in AC routing to distribution legs within the trunk station, and possibly for use in other locations where use of a fuse is required. Further investigation and field testing may be needed before general system use.

Spark Gap Transient Protector (SVP)
<u>Type Device:</u> Transient suppressor, voltage shunting device.
<u>Clamping/Firing Level:</u> Usually 200% of rated device voltage; 145 volts for most current devices in use. Early 30V systems used 90 volt units; some AC supplies use a 230 volt SVP.
Most modern equipment employing SVP's use 60A or greater self-resetting SVPs. While these are more rugged than earlier versions, the limitations and concerns listed below still apply.
<u>Firing Time:</u> 2 to 10 microseconds
<u>Where Typically Used:</u> Inputs/Outputs of coaxial lines in equipment.
<u>Characteristics:</u>

- Only device that can be placed directly across RF lines; very low capacitance.
- Fairly fast firing time; is dependent upon transient rise time.
- Can short from transient(s) and create an outage.
- Can open and become ineffective without the operator knowing the status of unit.
- Ionizes under multiple transients and becomes conductive; therefore may pass multiple transients on through the system.
- Primary application in present equipment seems to be to protect under-rated equipment "components" from overvoltage conditions.

<u>Recommended Use:</u> Not recommended for use in cable systems assuming proper voltage rating is employed in equipment components.

Metal Oxide Varistor (MOV)
<u>Type Device:</u> Transient Clipper or Limiter
<u>Clamping/Firing Level:</u> 200% of rated voltage.
<u>Firing Time:</u> Depends on transient rise time
<u>Where Typically Used:</u> On primary (AC) side of power supplies, sometimes in line equipment power supplies.
<u>Characteristics:</u>

- Fairly fast acting; can handle large energies but for only a short time duration.
- Clamping time depends on rise time of transient.
- Limited life expectancy; MOV's are damaged by transients, even those associated with ferro-resonant AC supplies, and should therefore be tested or replaced periodically. Transient energy is dissipated within the device junction, which eventually destroys it.
- A non-standby power supply is quite rugged, the MOV therefore provides limited and questionable protection in that application.

<u>Recommended Use:</u> Use in a **standby** unit to protect delicate inverter components may be of value depending on supply design and component selection. (Since the non-standby ferro-resonant supply is quite rugged, and the secondary of the supply forms a natural low pass network which inhibits the coupling of transients to the secondary, any real value in system transient suppression is questionable.)

Silicon Avalanche Diode (Mosorb™,**Tranzorb**™**)**
<u>Type Device:</u> Transient Clipper or Limiter
<u>Clamping/Firing Level:</u> Various, depending on device selected.
<u>Firing Time:</u> <1 nanosecond.
<u>Where Typically Used:</u> Typically used on the secondary side of the main AC power supply and in some line equipment power supplies.
<u>Characteristics:</u>

- Is available as a bipolar device; can be used in AC or DC sections in power supply design.
- Small physical size.
- Clamps and limits the transient at a specific voltage.

- Very fast acting and recovery; can handle large energies - but only for short time durations.
- Lead length affects clamping time and is therefore critical in equipment design application.
- If the surge or transient lasts for a long duration, the unit will fail since transient energy is dissipated at the device junction.

Recommended Use: **Possibly** in either the primary and secondary of equipment power supplies depending on design. The Tranzorb clips the transient at a designed level, while passing the remaining voltage on to the load. Since the device junction absorbs the transient energy, lifetime is limited.

Crowbar Circuits (AmpClamp™/Powerclamp™)
Type Device: Transient suppressor, voltage shunting circuit.
Clamping/Firing Level: By circuit design.
Firing Time: Typically in the microsecond range.
Where Typically Used: Used internally in amplifier power supply (primary or secondary, AC or DC) to shunt overvoltage conditions. Also at the AC output of main AC supplies by mounting externally at the power supply, inserter, or within the trunk station.
Characteristics:

- Can be designed for AC or DC applications.
- Very fast acting time; and **can handle very large energies**.
- Self re-setting at zero voltage crossover points in AC circuit design.
- Design is usually intended to blow a fuse in DC circuit design since a zero voltage crossover does not occur naturally.
- Cannot be placed directly across the coax ie a high impedance circuit. Current design therefore places them in power supplies, power inserters, etc.

Recommended Use: On the secondary of main AC supplies; in the primary and/or secondary of amplifier power supplies; and possibly further into the CATV distribution system. The crowbar circuitry typically uses an "avalanche diode" type device for over-voltage sensing, then fires the circuit which shorts the transient to ground through SCR's or a Triac. AC crowbars will fire and reset on each half-cycle, and can rapidly dissipate large voltage transients. **This allows the effective handling of large power transients under repetitive firing(s).**

It also appears that the crowbar circuit can be effective in handling some over-voltage conditions created by longitudinal sheath currents, which doubles its value for general CATV system use. The crowbar circuit is ideally suited for application within a CATV system, and its use is recommended in place of external MOV's or Tranzorbs.

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