Transient & Overcurrent Devices in CATV Plant Protection - Part II

IV. Grounding/Bonding Techniques

The DC resistance and AC impedance of the grounding system (ground vertical(s), connection points, grounding rod(s), and ground resistance) is also of major concern in cable systems for proper dissipation of voltage transients with resulting overcurrent conditions.

The DC resistance of the grounding system relates to the systems ability to properly dissipate overcurrent conditions caused by longitudinal sheath currents, and elimination of potential differences between grounding or neutral conductors in the utility plant, poles or pedestals [non-transient conditions]. The condition of connectors used at strand and ground electrodes, and attaining and maintaining a good ground are the primary determinants in success.

The AC impedance of the system, which exists under voltage *transient conditions*, is determined by the following:

- The inductance of the ground wire (vertical), it does not change significantly with wire size.
- The length of the vertical run [determines overall inductance].
- How the vertical system is positioned; proper placement involves vertical and horizontal runs only with smooth bends. An esthetically pleasing system (looks good to the eye) many times employs poor practices in attaining low AC impedances.
- Using more than one grounding conductor and electrode, which places two grounding electrode systems in parallel and therefore halves the impedance of the system.

Summarizing, size of the ground conductor is not as important (NESC requires #8 at minimum) as is the overall length. The length should be kept to an absolute minimum given site conditions. This applies for both utility pole and service line (drop) bonding/grounding.

Investigation into longitudinal sheath current phenomena in CATV systems also indicates the following:

- The overall importance of frequent and quality (low impedance/resistance) grounds [not bonds].
- Proper location of bonds between CATV plant and power company verticals. Improperly placed or too many bonds may in fact increase the percentage of load imbalance current carried, the major contributor to long term longitudinal sheath current conditions in CATV systems.

In the final analysis, grounding and bonding issues can and should be treated separately - to assist in simplifying the myriad of issues involved. Bonding serves the primary purpose of meeting NESC code requirements, which in general has personnel safety as the main emphasis. Cable bonding procedures should be designed to meet NESC requirements only. Grounding serves to properly dissipate voltage transients in the CATV plant; through draining of the transient to ground, and enabling proper operation of transient shunting devices such as crowbar circuits which should be the main methodology in transient protection for the cable system.

Specific grounding and bonding recommendations are as follows:

Bonding Requirements:

- Every first, tenth, and last utility pole or pedestal (NESC requires 4/mile).
- The bonding jumper should be a smooth run of #8 [minimum] copper, bonded at the CATV strand with an appropriate Weaver-type bonding clamp, and at the power company vertical with the proper size split-bolt.
- Avoid placing bonds to the power company vertical at power company (secondary) transformer locations whenever possible. This will greatly reduce secondary load imbalance currents carried by drops and main line cables.

Grounding Requirements:

- A separate ground vertical and ground rod should be placed at each location where an external crowbar circuit is employed.
- If a [Pwr Co] vertical exists at the utility pole [or pedestal], a bonding jumper should be placed between the CATV vertical and theirs - at close to ground level whenever possible rather than strand level.
- For example, if crowbar circuitry [AmpClamp™, PowerClamp™, etc.] is used at each power supply location, each trunk amplifier, and line extender; then each of these locations should have a properly installed separate grounding system [vertical plus electrode], bonded to power company verticals as they exist.
- Excess bonds to the power company ground/neutral system should be avoided whenever and wherever possible, while still meeting NESC intent and code.

Additional Grounding and Bonding Guidelines:

- Use parallel rods and verticals where possible and as necessary; this halves the inductance of the system and achieves better "system to ground resistance", lower AC voltage (transient) drop in the grounding system, and reduced ground voltage gradients at the grounding electrodes themselves.
- Use of extra length ground rods to attain a better ground is not as effective, but can be employed where parallel rod methods cannot be used.
- Parallel (multiple) rods should be placed at a separation distance of: D = 1.1 X Rod Height. For example, two 8 foot rods should be separated by a minimum horizontal distance of 8.8 feet.
- Ground/bonding wires should be run vertically or horizontally only, with smooth bends in the wire where necessary.
- Proper drop bonding is also of paramount importance.

- Grounding/bonding connections should be checked and cleaned periodically to maintain good electrical connection. Corrosion prohibiting agents may be utilized to seal connections for improved long term results.

Proper Ground Resistance Measurements:
Finally, some discussion should be held on what constitutes a "proper ground". The NESC handbook defines adequate grounds in several different schemes, depending on the type of system the ground is employed in. In the "Single-grounded (Unigrounded or Delta)" system, the NESC states that "individual made electrodes shall, where practical, have a resistance to ground not exceeding 25 Ohms. In a single electrode resistance exceeding 25 Ohms, two electrodes connected in parallel shall be used".

In the "Multi-Grounded System", which more accurately describes the CATV plant, the codebook states the following: "Multi-grounding systems extending over a substantial distance are more dependent on the multiplicity of grounding electrodes than on the resistance to ground of any individual electrode. Therefore, no specific values are imposed for the resistance of individual electrodes."

Correspondingly, no specific individual electrode resistances are suggested in this document. A typical "adequate" value is understood to be around 25 Ohms or less. There are many instances where that value may not be attainable at a specific location, or perhaps in an entire area if unusual conditions exist. The practice recommended here is to measure a significant sample of the systems' grounds, to ascertain if adequate and proper procedures and methods are employed, thus attaining adequate grounds in the majority of cases. Where the majority of sampled grounds measured do not attain 25 Ohms or less, further investigation is recommended, and more stringent methods for the system may be necessary such as use of parallel rods, soil treatment methods, extra length rods [in some instances], better installation techniques, etc.

V. Recommended Device Application

1. Over-Current Protection..
An overview of system over-current protection device utilization in cable systems is as follows: Use of fuses should be acceptable in specific application(s); the AC input to the DC power pack to protect component parts and thermal runaway in the transformer (if employed in the circuit); at the output of the main AC supply [or inserter] for total supply current limiting; and for AC routing at trunk station distribution legs for current limiting in that individual distribution leg section. Also, depending upon system architecture, fusing may also be required at the trunk input/output points to protect against other shorted devices in the trunk system.

The main power supply should employ a fuse on the secondary side, either internal to the supply or in the power inserter, to provide overall supply over-current protection. Any complete short in the CATV system will, if close to the supply, blow the fuse taking the supply off-line from the system. The only other typical overcurrent condition of concern is a short in a distribution leg which might damage power-passing components plus load the trunk system sufficiently to reduce voltage at the trunk station power pack below acceptable levels. Fuse values of 150% to 200% of normal system draw (at that point) should therefore be employed. AC input to amplifier power supplies should **normally** be fused at the manufacturers recommended value with a MDL - medium blow or slow blow type.

Use of fuses or thermal breakers at amplifier (AC) inputs/outputs (as opposed to the power pack input) is generally discouraged unless special system equipment problems exist as described earlier. Overall, system overcurrent protection should be provided by the fuse at the output of the main AC supply for the trunk system, and the fuse at the trunk amp distribution leg for distribution system over-current conditions. Where fuses are located inappropriately in existing equipment or system design, buss bars may be installed to replace the fusing element.

The construction and layout of the modern CATV system, with large amounts of moderately resistive cable, plus the self regulating characteristics of the ferro-resonant power supply eliminates the need elsewhere in the system for fuse application. Finally, the present relatively low 60 VAC supply voltage defers a present need for fuse application resulting from human safety concerns; raising this voltage in future system operation may require new consideration in this area.

Specific device application and use is recommended as follows:

a)Fuses: Acceptable use of fusing in cable systems is as follows:
- Secondary of main AC transformer (supply) for overall system current limiting. The value of this fuse should be roughly 150% of the full rated output of the supply. For example, if the supply provides 5 amperes of current under typical system loading, the fuse employed should be approximately 8 to 10 amperes, medium or slow blow type.
- Primary of AC power packs where current limiting is required for protection of transformers [thermal runaway] and other components. The manufacturers' recommended fuse value should be used, with a MDL - medium-blow fuse used to prevent "nuisance" fuse failures. Where sheath current problems exist and tend to exasperate nuisance fuse blowing beyond acceptable levels, the value of the fuse could be increased in some instances.
- At the current routing point for distribution legs in trunk amplifiers. Since transient voltage and current conditions should be eliminated by other techniques, the purpose of the fuse at the distribution leg in a trunk station is to protect against "long term" over-current conditions caused by a short circuit or similar phenomena in the system. Fuse values should be chosen to reflect 150% to 200% of normal current conditions in the system at that point, and the fuse should be of the MDL or medium/slow blow type. For example, if the measured current draw on a distribution leg exiting a trunk station is 3.4 amperes, the installed fuse value should be approximately 5A to 7A, and of the MDL type. Since transients are suppressed in the system by other methods, the fuse will be tripped by overcurrent conditions only. 150% to 200% rating allows for isolation of the distribution leg under short circuit conditions, while eliminating "nuisance" fuse tripping in almost all other instances.

b)Mechanical Circuit breakers: The use of mechanical circuit breakers should be limited to the input of the main AC supply. Most AC supplies employ a circuit breaker on the primary side for AC disconnect capability. Continued use in this area is acceptable, while use in other equipment or the CATV trunk/distribution system is not recommended.

c)Thermal breakers: Thermal breakers may be found preferable to fuses in some aspects, but exhibit negative characteristics in the following areas: A cycling thermal breaker can "fuse" or short its contacts under repeated short circuit conditions, thermal breaker cycling on a permanent short can affect other bridger legs or the trunk itself (a short near the breaker can cause the trunk to cycle on and off during open/close conditions), the thermal breaker is temperature sensitive (current required to trip a given device changes over temperature variations in the system which affects overall device stability and accuracy), and use of thermal breakers in a system tends to make system troubleshooting confusing.

After much research and consideration by this firm, the use of thermal breakers is not recommended in cable systems or equipment. The "basic" underlying theory of application for the thermal breaker is to protect against a "temporary short circuit condition in the system, then reset once the shorted condition has cleared". That does not describe the typical short circuit occurrence in a cable system, which rarely occurs but which stays shorted once created. A better approach is to eliminate transients from the system entirely, then protect against shorted conditions with a properly chosen fuse.

2. Transient Clipping Devices..
Transient suppressors [both clipping and shunting devices] are necessary in cable systems to suppress and eliminate the effects of voltage transients (fast rise and fall time) from storms, power company switching, and other phenomena. These induced (or sometimes directly coupled) voltages cause extensive equipment damage, and can cause large currents to flow in CATV system while seeking an adequate ground at the transient frequency. Listed in the following text are primary types of transient protectors with recommended use in cable systems. Properly chosen transient limiting devices will:

- Not interfere with the system under normal conditions.
- Have adequate clamping speed to protect desired equipment during the transient.
- Withstand surges *without damage or failure*.

A suggested philosophy for transient clipping devices in cable systems is as follows: Lightning, power company switching, plus other phenomena create transients in the CATV system. CATV systems and equipment must contain proper protective devices if these transients are not to cause premature failure of equipment with resulting outages. Proper deployment of transient protection also allows for the application of proper system fusing techniques as discussed in the prior section.

Metal Oxide Varistors (MOV's) and Silicon Avalanche Diodes (Tranzorb™) are devices which are often employed in equipment, and which offer some protection against transient voltages. They tend to be fairly fast acting and can offer an adequate means of protection in many instances. The concern with these devices is their level of susceptibility to damage from the transient itself. These devices dissipate the transient energy across the junction of the device, generating large amounts of heat with corresponding device degradation. In general, MOV's could be employed on the primary of the main AC supply only, while Tranzorb™ can be utilized on the secondary of the main AC supply, and in the primary/ secondary of line equipment power supplies as designed by the manufacturer. Proper use of this circuitry should be considered one determining factor in the choice of line equipment utilized by the cable operator.

Specific device application and use is recommended as follows:

a)**Metal Oxide Varistors** (MOV's): Potential use is on the primary of main AC *standby* power supplies. MOV's should not be used on the secondary side of the main supply or beyond, as they are susceptible to transients created by the ferro-resonant device itself. Most power supply manufacturers have optional MOV-type devices available for installation in the AC supply circuitry. Typical ratings are from 40 to 200 joules (energy handling capacity). 200 joules is considered too large a device for CATV applications; 40j to 120j is therefore recommended when a MOV is employed.

At this juncture, it must also be pointed out that a ferro-resonant transformer is an extremely rugged device with heavy windings that form a natural low-pass network which inhibits any transient on the primary side from being coupled on to the secondary. The presence of an MOV on the primary side of a non-standby device is therefore of limited use, in either protecting the transformer or in inhibiting transient coupling to the secondary. Use of MOV's in non-standby supplies is therefore not recommended as it provides no real measure of protection. Use in standby units can provide limited protection for delicate inverter components and is recommended given the above qualifications.

A remaining problem with MOV's is their susceptibility to failure without direct indication they have been damaged. It is therefore recommended that systems which employ MOV's select an "indicating-type MOV" to show whether the device is functional or failed.

b)**Silicon Avalanche Diodes or Tranzorb**™: Use is recommended in line equipment power supplies, assuming correct circuit application by the manufacturer. Many line equipment manufacturers employ tranzorb-type devices in their power supplies - in the primary and/or secondary circuitry. Tranzorb's™ have very fast clamping speeds (less than one nanosecond), and are very effective in eliminating transients in equipment thus protecting sensitive semiconductors. These devices can be an excellent defense against semiconductor damage in equipment, depending on design. Wherever used in circuitry, the Tranzorb™ circuitry should employ some method of current limiting, as they tend to be damaged by large surges. It is also suggested that you may wish to examine the manufacture's circuitry, to ensure proper application of current limiting devices before final equipment selection is made. The Tranzorb™ is not well suited for external system application, as will be discussed in the transient shunting device section which follows.

3. Transient Shunting Devices..
Crowbar circuits are designed for transient or overvoltage conditions which allow for shunting of the voltage transient (the entire voltage waveform) to ground potential. Crowbar circuits are sometimes designed into line equipment power supplies, and also are

designed as external circuits such as the AmpClamp™ or PowerClamp™. They are **ideal** for use in a cable trunk/distribution system, where one half of an AC voltage waveform with accompanying transient may be shunted to ground potential without taking the entire system down! The power supply in each amplifier will continue to work for several cycles on loss of voltage, therefore a shunting during a transient condition for one half cycle produces no visible effect at the subscribers television. Initial applications of crowbar circuits are their proper employment in line equipment (for example, one line equipment manufacturer uses them on both the AC and DC side of their power supplies in each trunk station), and externally introduced into the trunk system by mounting in the power supply, power inserter, or into a specific trunk station by means of the power supply or fuse holder. Possible crowbar application in the <u>distribution</u> <u>system</u> by placement into a directional coupler type housing also appears to be effective in some instances.

Spark Gap Transient Protectors appear to offer little protection against system transients, and experience with SVP's used in cable systems over extended periods of time indicate that the SVP's eventually become the primary source of system short circuit failures as they eventually fail, blowing fuses and taking sections of the system off-line.

Use of crowbar type circuitry in locations such as the main AC supply secondary, and primary and secondary of amplifier power supplies is considered to be the primary method by which cable can reduce or eliminate system transients; while increasing overall equipment reliability. Conversely, use of SVP's is discouraged unless it is the equipment's only method of transient suppression. Frankly, equipment design which incorporates the SVP as its primary means of transient suppression should be considered suspect in terms of providing adequate protection for long term reliability in a transient environment.

Specific device application and use is recommended as follows:

a)Crowbar Circuits (AmpClamps™, PowerClamps™, etc.): Recommended use is on the secondary of main AC supplies in the power inserter area (or internal to the main AC supply or trunk station); and in the primary and/or secondary of amplifier line equipment power supplies where the manufacturer offers this as part of their standard circuitry. The AC crowbar provides the best **known** method for transient suppression in a modern cable system.

b)Spark Gap Transient Protectors or SVP's: Use of SVP's in cable line equipment is <u>not</u> recommended. Past tests and experience, with cable and other cable operators, demonstrate that protection derived from SVP devices is limited. Further, repetitive transients ionize the SVP chamber, and pass surges directly on to equipment in many instances. Finally, their lifetime is limited with an open or shorted SVP the final result. Use of transient shunting devices/circuitry other than SVP use in line equipment design will therefore be considered one determining factor in the choice of line equipment purchased and utilized in cable systems.

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