LIGHTNING AND SURGE PROTECTION OF CATV FACILITIES

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CATV facilities, generally, operate in an exposed condition to both power and lightning influence. All CATV systems require protection, not only for the system components but, also, for the connecting power service and subscriber drops. Proper application of voltage-limiting devices, such as gas tube arresters, and the proper use of bonding and grounding methods will provide the required protection.

Everyone, like it or not, is in the communications business. In talking to people, as I am to you, selling things, getting ideas or opinions across, handling work, and just about anything else you can think of, communication is an integral part. It is a basic ingredient in the recipe for living, and success in life depends largely on one's ability to handle it.

The CATV industry has recorded a remarkable growth in a short span of time. No doubt this is just the beginning. The capacity of the CATV facility to deliver information, in both one and two-way systems, is limited only by the imagination and man's own ability to conquer the associated problems.

For many reasons, systems builders in the past have paid very little attention to or made adequate provisions for lightning and power surge protection. Proper coordination and bonding procedures are, in most cases, either nonexistent or not maintained after they are installed initially.

In an effort to simplify the situation to the fullest extent, the following discussion of problems, which no doubt most of you, as I, have seen, will begin with a review of Ohm's law.

$$E = I \times R$$

E = Electromotive Force or Voltage
I = Amount of Current Flow or Amperes
R = Resistance, or Impedance, when dealing with anything other than Direct Current (Impedance is the combination of Resistance, Capacitance and Inductance, in any combination, when Alternating Current (AC) is flowing in the circuit)

Question No. 1: If we have a cable whose surge impedance is 100 ohms and it is in contact with 15,000 volts, 60 cycle AC, what is the current flow?

Answer:
$$E = I \times R$$
$$15{,}000 \text{ v.} = I \times 100 \text{ ohms}$$
$$I = \frac{15{,}000}{100} = 150 \text{ Amperes}$$

Question No. 2: What is the current flow if a cable whose surge impedance is 100 ohms is in contact with 1,000,000 volts?

Answer:
$$E = I \times R$$
$$1{,}000{,}000 \text{ v.} = I \times 100 \text{ ohms}$$
$$I = \frac{1{,}000{,}000}{100} = 10{,}000 \text{ Amperes}$$

The first question above can be easily related to CATV plant in contact with ordinary, primary power company distribution voltages. The second question can be related to a very weak lightning surge.

Power related surges in CATV plant are destructive in that they are relatively long in duration and produce large amounts of heat wherever shield resistance is highest. This usually results in fusing (melting) of the shield, metal separation, then arcing and possibly fire, if around low temperature or kindling materials such as wood and polyethylene.

Lightning related surges differ from power related surges in that they are of very short duration, very high voltage, and very high current. Voltages in the millions of volts. Current in the hundreds of thousands of amperes. Duration, several hundred milliseconds or at most, or longest, one-tenth of a second.

Time does not permit a thorough examination of lightning. We will simply accept the fact that it exists, discuss how it can damage CATV facilities and devices connected to CATV facilities, and what can be done to effectively reduce damage and outages to a minimum.

Cloud-to-earth lightning strokes are the specific "lightning" which is most damaging to exposed plant. Lightning may contact directly any part of the CATV system. This is the most damaging form of influence, as a part of the CATV plant is in the direct path, or circuit, between the cloud and the earth. The impedance of the CATV plant is so low in comparison to the overall circuit that we can simplify the situation and say that the cloud is a constant current generator during the stroke. Lightning strokes, as seen by the human eye, consist on the average of five strokes, the first being the most severe. Lightning, therefore, is AC; and its noise properties or influence extend upward several hundred kilohertz in the power spectrum. Lightning surge current peaks can reach magnitudes of several hundred thousand amperes. This produces forces which have a crushing effect upon conductors and which build to explosive levels in insulators or semiconducting materials, such as wood or brick. Persons struck by lightning receive a severe electrical shock, usually accompanied by burns. These persons can be safely handled immediately and should be administered artificial respiration immediately to restore normal respiration and pulse or heart beat.

CATV plant damage due to lightning allows the exercise of economic discretion with regard to protection requirements. From Weather Bureau charts and stroke factors, predictions can be made as to how many times per year any portion of the CATV plant will be affected by lightning. The protection against electrical shock to operating personnel and users is of uncompromising importance. Practical protection engineering will provide adequate protection and prevent needless expense or overprotection.

CATV "Head-Ends" usually employ very high structures to support antennas to receive signals. These structures provide favorable discharge points for lightning strokes that would otherwise strike the earth in the same vicinity. The higher the structure, the more the influence. These antennas conduct very high surge currents into the head-end facility and, also, into the trunk and distribution facilities, if the head-end facility is not adequately bonded and gounded. A single pointed rod, with the point upward, several feet above the highest antenna, metallically connected to the steel tower or bonded by straight wire down a wooden pole, and connected to a good "earthing" electrode, will diminish appreciably if not eliminate direct hits on high antenna. Insulated antenna elements can be effectively "grounded" to lightning by using quarter-wave shorted stubs attached at the antenna terminals. All coaxial downleads should be bonded at the top and bottom of the tower or pole structure. At the bottom, before entrance to the head-end facility or building, bonds should be placed to the "earthing" electrode, power company neutral, and water system metallic piping, if available. All coaxial cables extending from the facility should likewise be bonded in the same way. Straight #6 copper wire should be used and is sufficient, if not buried in the earth below ground level. Buried ground conductors should be #2 copper or equivalent.

Large currents introduced into CATV head-end equipment may be affected to a great degree by many electrical factors. In order to protect personnel from hazardous voltages, each component part mounted in each rack should be bonded together with a #6 ground wire and this wire ultimately terminated at the same point as the other ground conductors. Keep all ground conductors as short as possible.

A discussion of conductor impedance to lightning at this point should be helpful. If we compare a copper wire that contains twice the copper as another copper conductor (#3 CU vs. #6 CU), the large conductor will only improve our surge impedance to lightning about 28% over our small conductor! If we use two #6 CU conductors in parallel, we improve the surge impedance to lightning by about 68% over one #6 CU conductor. Therefore, if we bond everything together, we greatly reduce the surge impedance to lightning and reduce our susceptibility to damage from lightning. This is also true with power contacts to CATV facilities. The higher the fault current, the faster the operation of the fault current devices.

CATV transmission line is unbalanced and, therefore, very susceptible to any electrical impulse by induction, capacitive coupling, or direct contact. The susceptibility can only be reduced by reducing the "shield" current, and the most effective way is to provide as many parallel conductors as possible. Bonding of the CATV shield to the power company multi-grounded neutral, the telephone company cable shield, and the pole ground effectively reduces the surge impedance of the CATV plant to lightning.

Periodically, depending on system design, amplifiers are inserted in the transmission line to amplify the useful information. Today these devices are completely solid-state and are very susceptible to surge effects. Gas tubes provide effective means for protecting these devices from lightning and power-induced surges. Two, two-element devices are now used, but a superior three-element device is now available which can be employed to more effectively by-pass all surge conditions. The three-element device exhibits very low capacitance to the input and output of an amplifier and can carry several magnitudes of current greater than existing two-element devices. It is virtually transparent from zero to 300 megacycles; however, some redesign of amplifier cases may be necessary in order to keep lead lengths as short as possible.

Distribution and trunk line power supplies connected to power company distribution facilities offer another use for three-element gas tube protection. Unsymmetrical phase voltages, between two CATV power sections, may cause very high voltages to appear on the CATV conductors. These voltages can be effectively suppressed by three-element gas protectors installed on the power supply units. By careful design, with surge protection as one of the paramount criteria, systems can be made much more reliable than envisioned today and, possibly, with much reduced maintenance costs to the operator. System reliability will begin to be more important as time passes.

Terminating a CATV system in the customers' premises presents an interesting exercise in how surges on the system can cause outages. If we admit that the power company and telephone company have bonded their station grounds together and to the water system, if possible, then how do you, as CATV operators, do the same? It does take persistence in most cases. First, the shield of the CATV drop should be metallically bonded to the power company's neutral and the water system, if metallic. (The power company and telephone company grounds, normally, will already be connected to a good ground and bonded together; and by connecting to this common ground, an effective common ground is maintained on the CATV facility also.) Routing of the CATV drop to the customer's premises to allow short bonds should be planned and executed.

Connection to the customer-owned television set is usually made through a transformer (75 ohms to 300 ohms). This transformer usually has very low insulation resistance or voltage breakdown. In addition, the input to the television set tuner is not much better. Power or lightning surges make "smoke" out of these two devices, because no attention is placed on common bonding at the television set. The shield of the CATV drop should be metallically connected to the chassis of the television set, and the chassis of the television set should be connected to the "common ground." The easiest and simplest way to accomplish this is to provide a three-conductor line or power cord to the television set. If this cannot be effected in its entirety, then a #6 copper wire must be run from the TV set chassis, as straight as possible, to the "common ground." This bond will prevent the TV chassis and CATV drop from being at different potentials and causing the television set's power supply from "arcing over" or puncturing the insulation on the transformer windings.

In conclusion, I hope that I have shared with you, in simple language, ways in which you can improve the reliability of your CATV systems and prevent damage to your equipment and your customers' connected equipment.

As Dave Bodle so aptly puts it, "No longer should lightning damage be accepted fatalistically as an 'act of God,' since the know-how and hardware exist today to minimize the adverse effects. The major aspect of the problem now is economics."

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