CONTROLLING POWER SYSTEM SURGES IN CABLE TELEVISION SYSTEMS

W. S. Campbell, P.E.
General Electric Cablevision Corporation
Schenectady, New York

This paper discusses the causes of commercial power system surges and presents recorded data indicating the nature, magnitude and frequency of occurrence of surges to be anticipated on 120 volt distribution circuits. The effects these surges can have on a cable system's reliability are discussed, and the various devices available for surge protection are reviewed. Particular attention is paid to a surge problem, and the corrective measures taken, in General Electric's Decatur, Illinois cable system. In Decatur, surges in excess of 1200 volts were indicated on residential, 120 volt circuits and repetition rates up to 480 surges in a 24-hour period were recorded at the output of one of the cable system's 60 volt power supplies. Finally, a modification for cable television use of the electrical protection section of REA specification PE-60 is offered. This modification provides voltage and current surge acceptance tests for cable television amplifiers and power supplies.

Three of the principal causes of surges in 120 volt power circuits are inductive load switching, lightning induced transients and direct lightning strikes to the power system. Probably every cable system has experienced both short term, self-correcting service interruptions and long term service outages caused by lightning. However, as the services carried on cable systems, particularly bidirectional cable systems, grow in complexity, the need for higher levels of system reliability and immunity to voltage transients and surges also grows. For example, one to two hour outages cannot be tolerated in a cable system carrying a burglar alarm and fire alarm service.

First, just what is the nature of the surges we encounter or can expect to encounter? What is their peak voltage, wave shape, frequency of occurrence and duration? We will omit any consideration of direct lightning strikes to the cable system since these result in large mechanical failures despite the best grounding and bonding measures.

In a general study[1] on 120 volt secondary power surges that took place over two years and at 400 locations in 20 cities, surges from 600 to 5600 volts were measured. Their wave shape was either unidirectional, with durations to 15μS, or oscillatory with one to four cycles of frequencies from .2 to 1 MHz. The wave shape varied considerably from city to city and even location to location within a given city and was dependent upon the impedence of the power system at that particular point.

Although many of these surges were lightning induced, even surges within homes caused by water pumps, fluorescent light switching and oil burner starting were from 500 to 2000 volts! Although many surges greater than 4000 volts were recorded, if it is possible to draw a "typical" lightning induced surge, it would look something like Figure 1.

Surges are present almost all the time, at almost all locations and at surprisingly high voltages. One of the most convincing pieces of evidence for this is the fact that when General Electric increased the winding insulation in their 120 volt electric clocks from a 2000 volt withstand to a 6000 volt withstand[1], motor winding failures were reduced by a factor of 100:1!

These are the surges we must live with. How? There are three main classes of surge protectors or arresters: zener diodes, metal oxide varistors and spark gaps. Each of these devices has its advantages, disadvantages and area of application. The device currently being used in cable television amplifiers is a spark gap sealed in an inert gas atmosphere - commonly called a gas tube. The gas tube has two main disadvantages: a time delay in establishing the arc and a difficulty in extinguishing the arc. The first can allow fast rise time pulses of considerably higher voltage than the tube's DC firing voltage to pass. Because of the gas tube's second difficulty, the arc in a gas tube that does not have a series limiting resistor can be maintained with a much lower voltage than that required for arc initiation. The arc may even be maintained on the normal 60 VAC powering voltage; this can lead to destruction of the gas tube, leaving it fused in a shorted condition.

The first stage in surge protection occurs in equipment selection for the construction of new cable systems. It is hoped that the surge specification included as an appendix will help in this. This is a modification of the surge portion of REA specification PE-60, "Trunk Carrier Multiplex Equipment", that we have included in our general construction specifications. Figure 2 shows the type of surges this modified test specification applies to cable television equipment.

The most common surge problem, however, is in a cable system which already exists. This problem is particularly severe in General Electric's Decatur, Illinois system. Figure 3 shows the history of power related failures in Decatur. Although these failures include burned circuit boards, broken circuit breakers, circuit breakers requiring resetting and burned out power transistors, by far the predominate failure mode was the fusing of gas tube surge protectors. The turnkey vendor for our Decatur and Anderson systems, Anaconda Electronics, placed a Biomation transient recorder at the output of one of the Decatur AC power supplies and set it to record any time the output voltage exceeded 70 volts or dropped below 50 volts. In the 30 day recording period, 750 such excursions were recorded - 480 of them in one 24 hour period! General Electric had previously measured surges on 120 volt services in Decatur in excess of 1200 volts[1].

Although we are experiencing excessive power failures in both our Anderson and Decatur systems, certain areas of our Decatur system seem to be the hardest hit. We have increased our grounding frequency in these areas and now have another transient recorder on loan from the IEEE to our Research and Development Center installed in one of these areas.

Anaconda has taken two actions in the hope of improving their system's vulnerability to surges: they have provided 230 volt surge protectors to replace the factory installed 145 volt units and have installed large capacitors (Figure 4) at the output of selected AC power supplies. Unfortunately, neither action has solved the problem or, it appears, even diminished it.

In an attempt to determine the surge attenuation of the AC supply, a sample was loaded to an output current of 6 amperes into a nonreactive load and surges were applied to both the input and output at our Research Center in Schenectady. A 2kV, 5μS surge and a 2.5kV, 70μS surge were applied across the input line and from an input line to ground. In no case was more than 30 volts of the surge left at the power supply's 60 volt output. When the 2.5kV, 70μS surge was applied across the 60 volt output of the operating, loaded supply, the gas tube contained in the supply fired, clipping the peak value of the surge to 900 volts and then recovered, restoring the 60 volt output. This testing would seem to indicate that the surges causing our problems are not entering the system through the AC supply.

At the writing of this paper, the problem is still not solved. In conjunction with the General Electric Research Center, we are now investigating induced voltages and ground currents as possible causes.

(1) Surge Voltages in Residential and Industrial Power Circuits, F. Martzloff and G. Hahn, IEEE Transactions on Power Apparatus and Systems, July/August 1970.

(2) Bibliography on Surge Voltages in AC Power Circuits Rated 600 Volts and Less, Ibid.

APPENDIX

2.5 Electrical Protection

2.5.1 General

Adequate electrical protection of distribution equipment shall be included in the design of the distribution system.

The characteristics and application of protection devices must be such that they enable the distribution equipment to withstand, without damage or excessive protector maintenance, the voltages and currents that are produced in the equipment as a result of induced or conducted lightning surges.

All power supplies will be equipped with circuit breakers and a surge protector, and all amplifier trunk ports will be equipped with easily replaceable gas discharge surge protectors. All trunk amplifier bridger ports will be equipped with self-healing overload protectors.

Compliance with Specification 2.5 will be demonstrated to a representative of General Electric Cablevision Corporation on two randomly selected samples of each of the following: a "fully loaded" trunk amplifier station, an AC power supply and a line extender amplifier.

In each demonstration, the device being tested shall pass the following tests: (1) capacitor discharge test, (2) current surge test and (3) protector response delay surge test. The capacitor discharge test and the protector response delay surge test are performed with all protectors removed; the current surge test is conducted with all protectors in place. In each case, the device will be tested while it is in normal operation.

2.5.2 Capacitor Discharge Test

The magnitude of the capacitor discharge surge shall be the maximum DC breakdown voltage of the protector used and shall have a rise rate of not less than 100 volts per microsecond and shall decay from peak voltage to one half the peak voltage in not less than 100 microseconds. The rise rate is defined as the peak voltage divided by the time required to reach the peak voltage.

Five surges shall be applied at one minute intervals to each port of the device under test. The polarity of the surge generator shall then be reversed and the procedure repeated.

AC power supplies shall have the power input terminals surge tested by surges applied between the power input terminals and between each power input terminal and ground. The number, repetition rate and polarity of the pulses shall be as above.

2.5.3 Current Surge Test

A 500 ampere peak current surge with a rise rate of not less than 100 amperes per microsecond and a peak to half value decay time of not less than 1000 microseconds shall be applied to all ports and terminals as described in 2.5.2. Three surges of each polarity shall be applied at one minute intervals.

2.5.4 Protector Response Delay Surge Test

Additional capacitor discharge tests shall be performed to determine the ability of the equipment to withstand voltage surges encountered because of the operating delay time of the protector. These surges shall be applied to the ports and terminals and in the number, repetition rate and polarity described in 2.5.2.

The magnitude of the surge is the surge striking voltage of the gas tube, and the rise shall not be less than 500 volts/microsecond. The surge striking voltage shall be determined from the protector manufacturer's data, using a rise rate of 500 volts per microsecond.

Power supply AC power line input terminals shall also be given protector response delay surge tests. The striking voltage of the protector shall be determined at a 10kV per microsecond rise rate and the rise rate of the surge shall not be less than 10kV per microsecond.

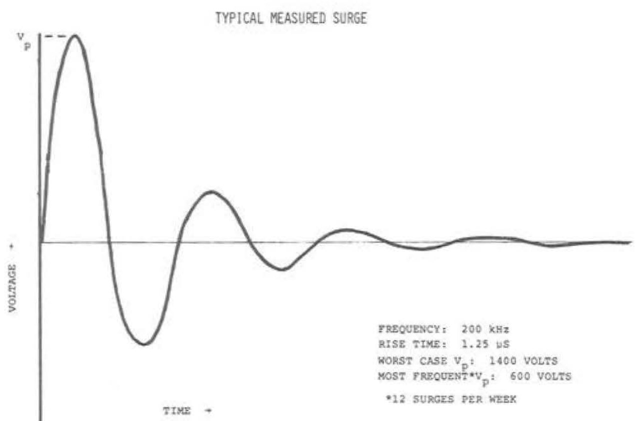


FIGURE 1

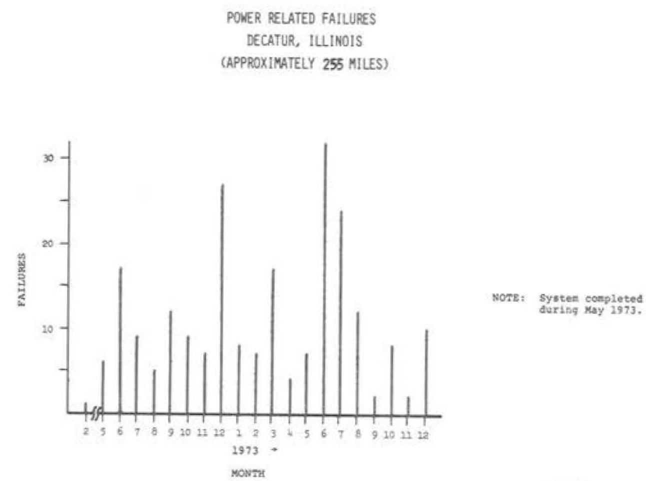
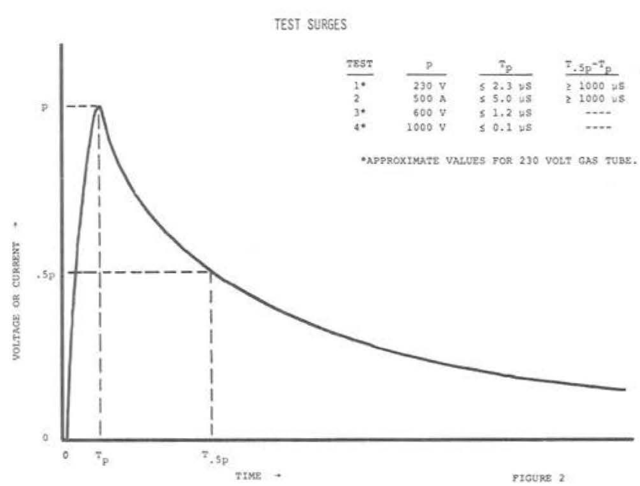


FIGURE 3



TEST	P	T_p	$T_{.5p}-T_p$
1*	230 V	≤ 2.3 µS	≥ 1000 µS
2	500 A	≤ 5.0 µS	≥ 1000 µS
3*	600 V	≤ 1.2 µS	----
4*	1000 V	≤ 0.1 µS	----

*APPROXIMATE VALUES FOR 230 VOLT GAS TUBE.

FIGURE 2

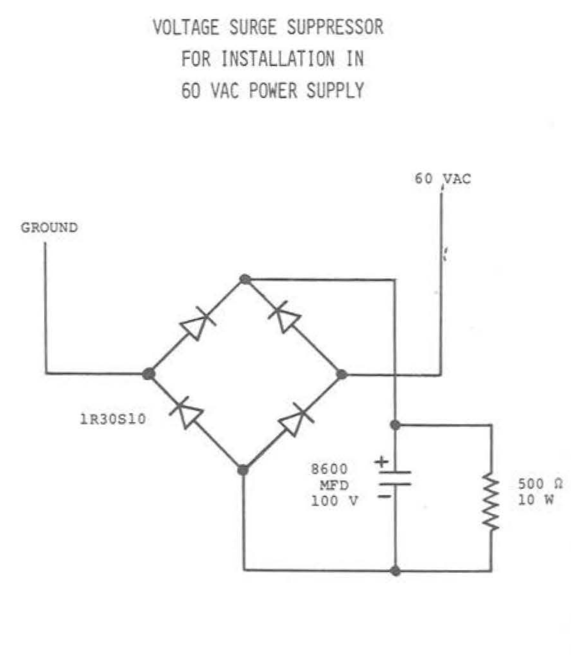


FIGURE 4