IMPROVED OUTAGE CONTROL USING A NEW AND UNIQUE TRANSIENT ELIMINATOR

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ABSTRACT

Outage control is an area of major concern throughout the cable television industry, not only from the standpoint of maintaining customer revenues, but also for insuring reliability and longevity of CATV system hardware.

Power problems can plague a CATV system. Transient voltage surges and spikes induced by lightning or caused by sheath currents and utility switching operations are a very serious threat to reliable cable system operation.

This paper will describe a new method for protecting the 60 volt plant. A design using extremely rugged semi-conductors to shunt surge currents to ground, enables active and passive devices to become essentially immune to damage caused by high voltage transients.

We will present the technical results of initial laboratory research, as well as actual cable system tests. A detailed description of how spikes and surges are created in the CATV environment provides a basis for evaluating effectiveness and reliability of this approach. Several illustrations supporting the research data are included.

Our paper proposes a unique solution to several of the contemporary problems facing all CATV system operators: Outage control, hardware protection and customer satisfaction.

INTRODUCTION

Numerous surveys have confirmed that interruption of service (after picture quality) is the second-highest cause of customer dissatisfaction. Technically, the reason for these long and short-term outages can be classified as follows:

HUMAN ERROR
*Under-fusing.
*Self-induced interruption during maintenance or equipment change-out.
*Disinterring of underground plant or driving fence posts through it.
*Oversized vehicles tearing down overhead plant.
*Poor installation causing "pull-outs" during large temperature drops.
*Inadequate batteries or battery maintenance to support standby power.
*Vandalism.

NATURE
***Wind-related storm activity causing trees to fall on plant.**
***Electrical Storms (Lightning).**
*Ice

POWER PROBLEMS
*Blackouts
*Brownouts
*Surges
*Transients/Spikes (Dirty Power)

EQUIPMENT FAILURE
*Semiconductor Heat Prostration
*Catastrophic Failure

Apart from the obvious, the frequent mechanism of equipment failure is caused by lightning and dirty power. Note: Direct lightning hits, fortunately, are quite rare (and preventable). Amplifiers and other CATV equipment actually survive the majority of surges, spikes and other transient phenomena; however, they are injured in the process and slowly deteriorate until they "unexplainably" die, causing a surprise outage.

OUTAGE CONTROL

During the spring and summer months, many articles are published on Outage Control. From these come ideas that provide solutions to alleviate electrically-related problems. In general, these references include:

1) Drive unbonded grounds at separate poles. This provides a divider network that drains-off some of the energy under fault conditions, but there are limits. One-ohm grounds, which are created by coupling-up ground rods (to 32 feet in depth) and hitting underground water, do not completely solve the problem. Also, it should be noted that this technique can create large potentials between conductors on the pole.

2) Bridge the amplifiers with at least AWG #6 copper wire. This is intended to shunt the approximate 1000 Amperes flowing in the strand/cable during fault conditions and prevent a potential from developing across the entire assembly, including input and output connectors.

3) Increase fuse ratings incrementally. This is especially true where the equipment is sufficiently robust, such as the secondary of ferroresonant-type, 60 Volt power supplies which are short-circuit proof and "indestructible."

4) Institute Outage Tracking, Quantifying and Post-Mortem Analyses. A step-by-step procedure needs to be established which provides exact details of how each type of outage is to be managed, who is to be called, and under what circumstances. This type of management can help to reduce outage *duration*.

5) Attack surge and spike problems at the center-conductor. The one, single-step, safe and legal way to overcome power-related problems where the damage occurs, is by using a fast-responding, rugged, transient protector.

THE CROWBAR APPROACH

During the summer of 1986, I received a call from a 1000-mile system in Virginia which was repeatedly receiving electrical storm damage. This was a sizable county system and spread over a very large area. It was possible to determine the broad path of storms as they moved through the system by the trail of burnt fuses and modules left in their wake. The problems were further compounded by the fact that the power tended to be intermittent during the storms, as well as losing regulation. Fortunately, the power company was able to provide valuable information for the study. In the case of the direct influence of the storm, lightning would strike the primary, arc-over to the secondary/neutral and be followed by as much as 10,000 Amperes of AC fault-current flowing back to the substation. This traveled by whatever route it could find, for as long as 160 milliseconds, before the substation breaker could stop the flow. It was discovered that the fault-current was divided about equally between neutral and strand/cable, which was then equally divided again between the strand and cable. This gave rise to a cable sheath-current in the order of 2,500 Amps. It's not surprising that their amplifiers and fuses were blowing. (See figure 1)

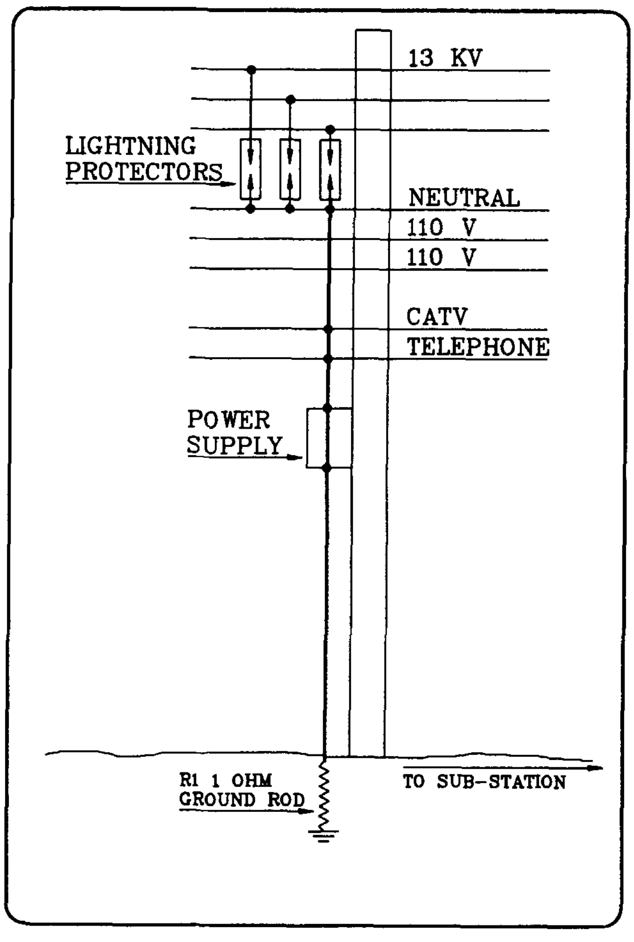

Figure 1

Even on normal, calm days during low-loading in residential areas, there will be at least 5 to 10 Amperes or more flowing in a strand/cable. It's an eye-opening experience to go around a plant with a clip-on ammeter and take strand/cable current-flow readings. Frequently, it is the areas with high, idle-currents that blow the plant away.

When contemplating the magnitude and duration of these currents, it is easy see why the small, ionized spark-gap pellets are inadequate for this type of service. They will either blow open, or closed, under prolonged high-current over-voltage conditions. When they are open, a false sense of security is created. When shorted, they are difficult to find and fix.

Since I had no access to a lab, I asked Tom Osterman at Alpha Technologies to build several heavy-duty transient-protection devices into power inserters. In my opinion, it was necessary to design a circuit capable of taking damaging fault currents to ground for several AC cycles. To be effective, the device required a response time of less than one microsecond. Trying to remove the transients by clipping, as in the case of M.O.V.'s and zener diodes, wasn't acceptable due to the high I^2R losses and low power dissipation capabilities. The best approach was to overcompensate for the energy rise by shunting everything, including the 60 Volt power supply to sheath ground.

Some purists may ask "What happens to the active devices during the three or four cycles when peak voltage is near 0?" The answer is that the power supply certainly doesn't care and the 18 to 22 Amperes that it can deliver to the semi-conductors is insignificant, compared to the main surge coming directly down the coax.

As for the active devices, they will typically stay up for approximately 100 milliseconds, by which time, a four to five cycle surge has ended or the power company breaker has terminated the surge; in which case, the question becomes academic. Standby power is available and full voltage will be returned on the first half-cycle when the fault overvoltage has ended. At worst, customers may see a one-frame roll. Is this not better than burnt fuses and modules, outages of an hour or more, and above all, techs performing repairs under inclement conditions?

The final requirement of this device was to insure high-reliability. The solid-state components would have to be extremely rugged and offer an almost indefinite life span, unlike MOVs with their ultimately self-destructing, tunneling phenomena.

Of the four units that we made for the Virginia system, one was installed directly in the storm path. No more damage was sustained in that area during the next five successive storms of the season. Interestingly, the plant surrounding and adjacent to the crowbar-protected plant was severely damaged as before. The second unit was installed in a pedestal enclosure at a new development where the 15 Amp supply was loaded to only 2 Amps. Everything connected to the power supply was being wiped out with every storm. After installation of the modified power inserter with the crowbar circuit, there have been no more problems on that leg.

I kept one unit and sent the other to a cable lab in Florida where they tried to test its survivability. Lab boss, Rick Miller put a flash capacitor charged to 1,500 Volts onto the device, which dissipated the energy without damage. Other tests included putting 120 VAC from a Variac into a crowbar unit, but the Variac got hot and repeatedly blew its fuse. Next, they applied 120 VAC from a 20 Amp breaker into it. The breaker tripped, but the device was unharmed. In desperation, we put 220 VAC on it from a 40 amp breaker. Again, the device sustained no damage. That was the extent of testing they could perform with their limited resources. After some minor improvements to the design, we sent one of the newer models to a system in Little Rock, Arkansas, experiencing a problem with very dirty power (VDP) coming from an adjacent, high-voltage power switching center. Fuses and equipment were blowing repeatedly. After installing the crowbar, no more equipment was lost, but fuses still blow on occasion. It may take two of the devices, several spans apart, to completely eliminate the problem. Fortunately, a power inserter with the crowbar circuit can be dropped-in anywhere; you don't have to actually insert power!

By this time we had missed the rest of the 1987 storm and lightning season. Since then, we have installed a few Crowbars in Central Florida (The "Lightning Capital" of the USA), awaiting the summer storms of 1988. It was then up to Tom at Alpha Technologies to perform the more sophisticated testing and analysis.

TESTING AND ANALYSIS OF THE "AMP CLAMP"

Identifying the exact nature of transient phenomena and developing a fail-safe solution required re-thinking the age-old problem of power protection. Following some of Roy Ehman's suggestions and practical field expertise, we approached the development of the "Amp Clamp" from the ground up.

Transients can occur randomly, or repeatedly. Repeatable transients, such as commutation voltage spikes, inductive load switching, power factor correction, etc., are easier to observe and eliminate than random disturbances. In the CATV AC power environment, transients can sometimes be traced to local industrial operations where large motors, compressors, welders, and other forms of heavy electrical equipment conduct dropouts, or produce "load dump" inductive-voltage flybacks onto the AC power line.

Most ferroresonant-based CATV power supplies will do a consistent job of protecting their AC loads from damage. Excellent common mode rejection and spike attenuation is inherent in the ferroresonant transformer topology. With most of the repeatable utility AC transients filtered out by the CATV power supply, the focus shifts to random events, such as lightning-generated transients on the CATV cable.

The device we developed to provide the voltage-triggered, low impedance short circuit to ground, consists of two, high-current SCRS (Silicon Controlled Rectifiers) connected in opposite polarity across the center conductor and sheath of the CATV cable. The most effective, and convenient, location for this device turned out to be inside of a standard, Jerrold Power Inserter which provides a weather-proof enclosure, as well as access to the cable conductors. (See figure 2) The SCR's are triggered into their conduction state by a voltage sensitive, bi-directional trigger diode. The diode provides a fast voltage level-sensor that gates the proper SCR into conduction which corresponds to the polarity of the voltage transient presented to the circuit. (See figure 3)

The SCR's have a steady-state current rating of 35 Amps and a one-cycle (8ms) pulse rating of 500 Amps. When an SCR is triggered into conduction by a voltage spike exceeding the threshold of the trigger diode, it will conduct current only until the current source falls close to zero. On the next AC half-cycle, the SCR that was conducting will become reverse-biased and turn off. If the transient re-occurs during this half-cycle, the opposite SCR will conduct until zero cross. (See figures 4 - 7)

The SCR's are extremely rugged devices in the pulse current mode. Voltage spikes will be clamped to ground without damaging the SCR because of the limiting effect of series resistance and inductance between the voltage source and the clamp circuit. This reactance will limit the maximum current flow through the clamp circuit. It's important to note that there is a forward-conduction voltage drop of 1.8 Volts across the device.

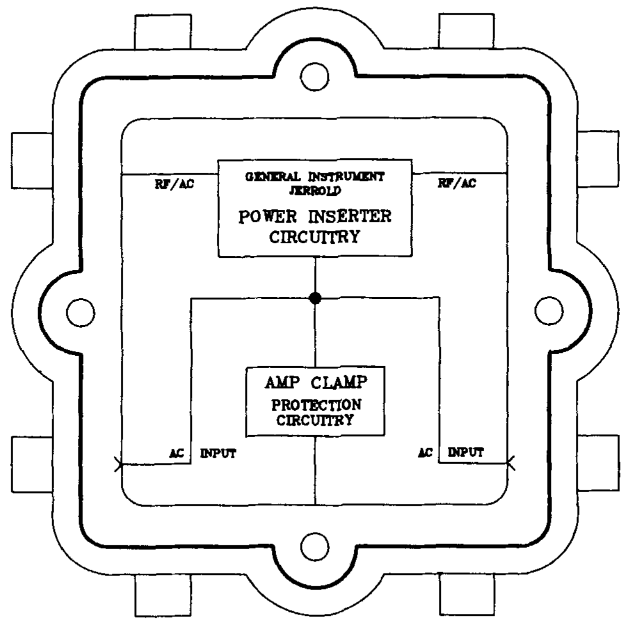

Figure 2

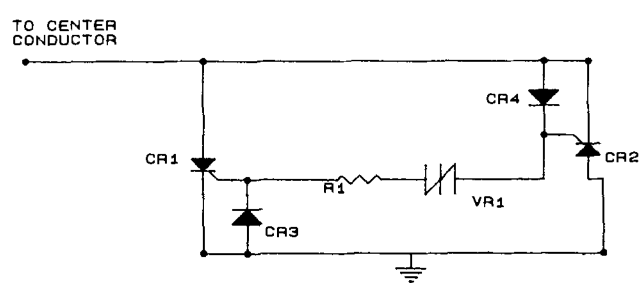

Figure 3
Amp Clamp schematic diagram.

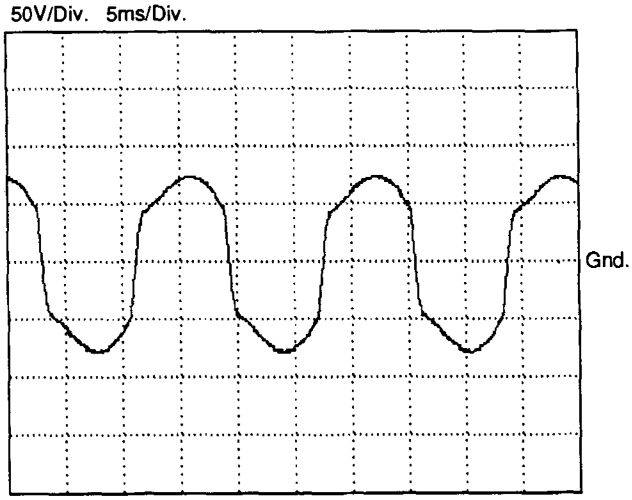

Figure 4
Normal 60V power supply output waveform.
(full load 16A)

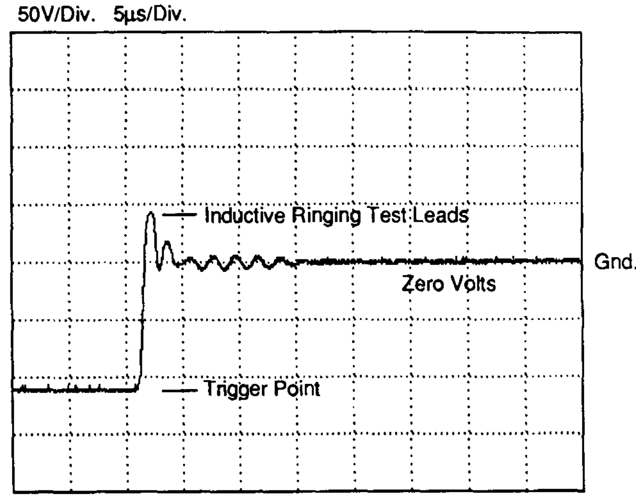

Figure 6
Enlargement of clamp action
(from figure 5).

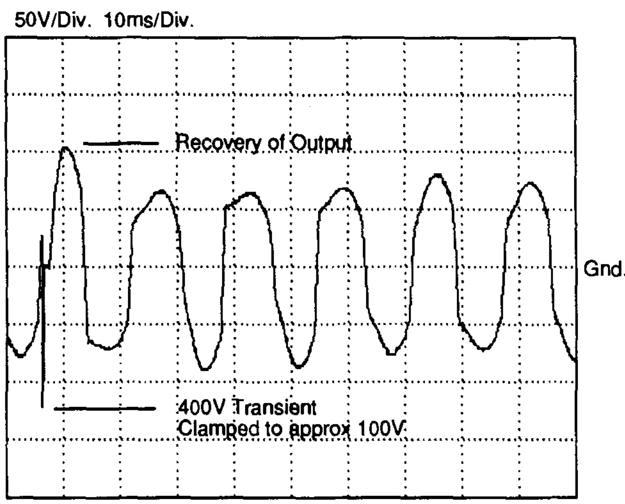

Figure 5
60V power supply output waveform
with 400V transient applied.

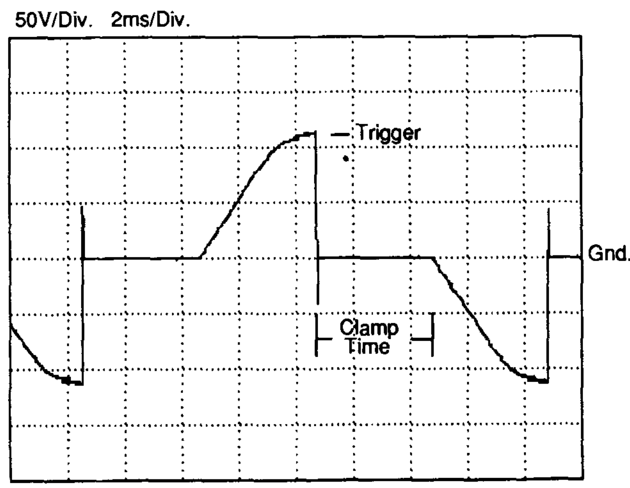

Figure 7
Amp Clamp subjected to 120VAC
Note: Trigger point and resulting
clamp to ground.

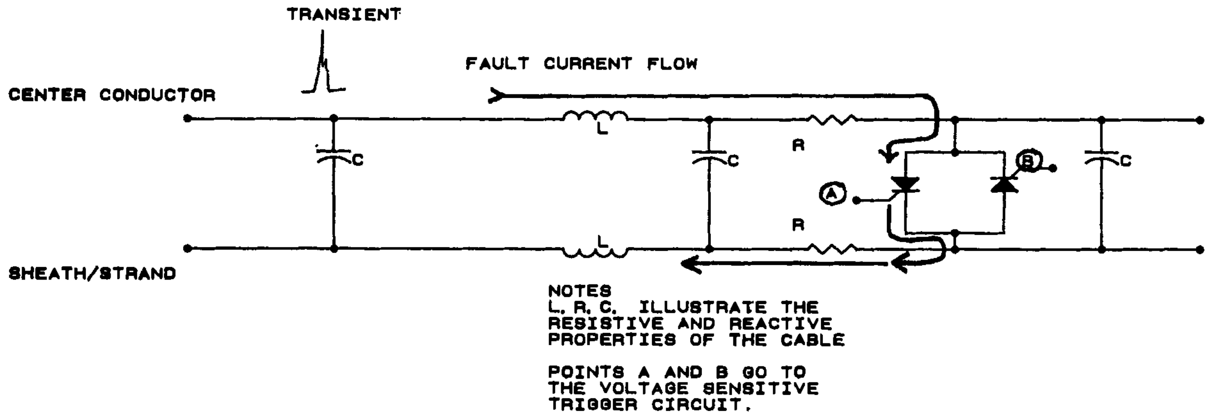

Figure 8
Equivalent Cable Circuit Description

The minor disadvantage of this circuit is the phenomenon called "power follow". Once the clamp is triggered into conduction mode, current provided by the local AC power supply will be clamped close to ground, as well as the fault current. This will cause a maximum AC interruption of 8.3 milliseconds or 1/2 cycle (60Hz). This occurrence will not harm any ferroresonant-type power supply and will not cause most trunk amplifiers to drop out due to the approximate 100 milliseconds of "hold-up time" resulting from the large DC input filter capacitor located in the internal 24 VDC power supply.

To fully test this device and determine its effectiveness and survivability, we embarked on a program of component stress analysis and "real world" transient simulation. In the fall of 1987, we took several prototypes to an independent high-current test laboratory for IEEE 587 surge voltage protection compliance testing. We used a Keytek high energy surge generator to produce surges specified by IEEE 587, Part A (6,000 Volts - 200 Amps) and IEEE 587, Part B (6,000 Volts - 3,000 Amps). Other aspects of our test program included direct connection to 40 Amp 220 VAC power circuits, high current discharge from multiple capacitor banks, continuous operation in conduction mode at 30 Amps, and thermal cycling of the clamp components. With repetitive hits, we were unable to cause a single failure to ANY of the active components in the power inserter or the Amp Clamp circuity. The unit clamped the high energy spikes faster and with a lower amplitude than any of the M.O.V. surge arrestors that we took along for comparison!

One unique feature of the circuit layout is the press-fit heatsinking of the SCR's to the die-cast power inserter case. Any potential heat generated by the fault current flowing through the SCR's is quickly dissipated by the large mass and surface area of the power inserter case. This function minimizes the thermal stress on the SCR's when they are conducting, thereby greatly increasing the reliability of the device.

As a result of this new design, transients can be quickly and safely clamped to ground, thus protecting active and passive devices in the CATV system, without interruption of service or degradation of equipment. To date, the feedback from system operators that have installed Amp Clamps in areas that consistently experience outages and equipment damage due to lightning strikes has been very positive.

The "Amp Clamp" (See figures 2 and 3), can be easily built in time to protect your plant from this summer's storms. This is an exciting application because of its significant contribution to industry-wide outage control.

REFERENCES

1. Roger Brown CED August 87
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3. Roy Ehman CED Nov/Dec 85
4. Jeff Geer Alpha Technologies
5. Craig Lang Alpha Technologies