Transient Control Levels: A New Concept Licks an Old Telco Problem

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Significance
Part 6: Textbooks, tutorials and reviews.

This invited trade magazine article introduced to the Telco community the concept of “Transient Control Levels” initially developed in 1975 for equipment connected to AC power circuits. In this case, the AC power input port of central switching facilities would also be considered. Furthermore, the editors of the article chose to suggest that the concept could also apply to signal lines, with appropriate levels.

TRANSIENT CONTROL LEVELS
A new concept licks an old telco problem

Overvoltages are here to stay, and they cause more problems than ever with sensitive electronic gear. The industry, can, and must cope.

By F. D. Martzloff*

Transient overvoltages are here to stay; we can only learn to live with them. The electrical and electronic equipment of yesterday could survive the effect of these transients because of conservative designs with built-in capabilities. But today and tomorrow's equipment depends on sophisticated, miniaturized solid state devices. Because they are very sensitive to overvoltages, these devices cannot survive transient overvoltages if not protected.

The transients we are discussing here occur on power systems as well as on signal lines. They are overvoltages caused by natural events such as lightning or high-voltage wires falling on lower voltage lines, and by such man-made events as load switching, intermittent contacts, or coupling from adjacent circuits.

While transient duration is extremely short—a few millionths of a second (microseconds)—transient amplitude can exceed 10 to 20 times that of the normal circuit voltage (see photograph). This overvoltage can cause component failure, sparkover between wires followed by a power arc, and mistriggering of solid state devices. This damage to equipment, on the power supply side as well as on the signal lines side of the telephone plant, is the main issue here rather than the nuisance effects.

Successful survival depends on a technically sound, cost-effective coordination among the environment (transient occurrence), the equipment design (withstand capability), and the use of protective suppressors (voltage clamping). Such a coordination has been developed in the electric utility industry with great success, but the electronics industry as a whole, including the communications people, has not yet been able to develop, to accept and to enforce a rational system of coordination. The *Transient Control Level* (TCL) is a plan for systematically coordinating the three parameters of environment, equipment and protection.

The TCL approach proposes four specifications:

1. Equipment will be designed to withstand well-defined "proof tests," rather than inconsistent simulations of an uncertain environment.
2. Both the power lines and the signal lines of an electronic black box will be subjected to proof tests.
3. A limited number of tests levels will be established; from the range of these the manufacturer and the user together will select a particular level for a given application.
4. The waveshape (the value of the overvoltage as a function of time) and energy content of the transient will be defined by established guidelines.

These four specifications for TCL are rooted in several hard facts. Users and manufacturers must accept the impossibility of simulating all possible transient overvoltages encountered by equipment in service. Nevertheless, equipment can be designed to withstand a standard transient, and experience has shown that if the standard is set properly, the field experience of the approved equipment is far more acceptable than that of equipment which has not met the standard.

Clearly, users would like to have high standards of withstand capability, while manufacturers, facing competitive pressures in an environment of undefined transient standards, would like to reduce costs by limiting withstand capability.

Actually, producing electronic equipment with high inherent transient withstand capability would be economic heresy. *To allocate resources to a balance between moderate capability and moderate protection cost is, in fact, the rational approach to the problem of equipment pro-*

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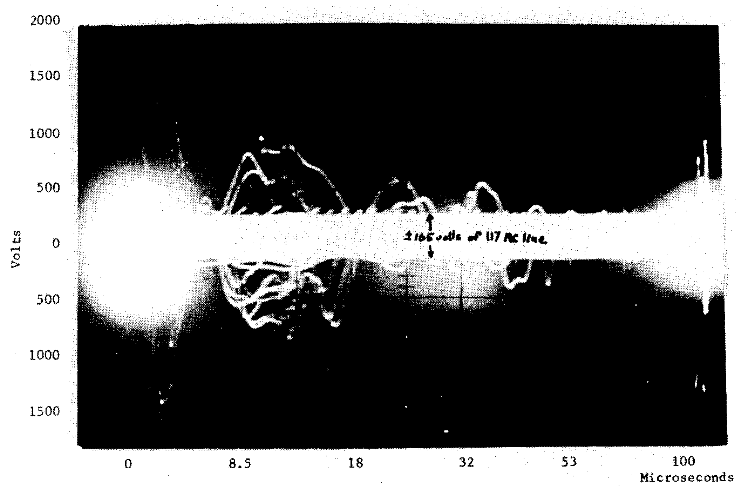

Oscillogram showing the overvoltages that can occur on a power system under conditions of switching transients. This was recorded over a period of 24 hours at the service entrance of a house in which a mercury switch was switching on and off an ignition transformer.

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tection. The key concept of TCL is that the coordination of environment, equipment, and protection not only can be best accomplished but will be most cost-effective if it is planned ahead rather than retrofitted—if a retrofit is possible.

In defining the standard test conditions, then, there must be a balance between the desire to produce high reliability and the desire to minimize cost. There is nothing new in this aspect of engineering. The novelty here is the fast pace of new equipment growth and of the progress in making transient suppressors available.

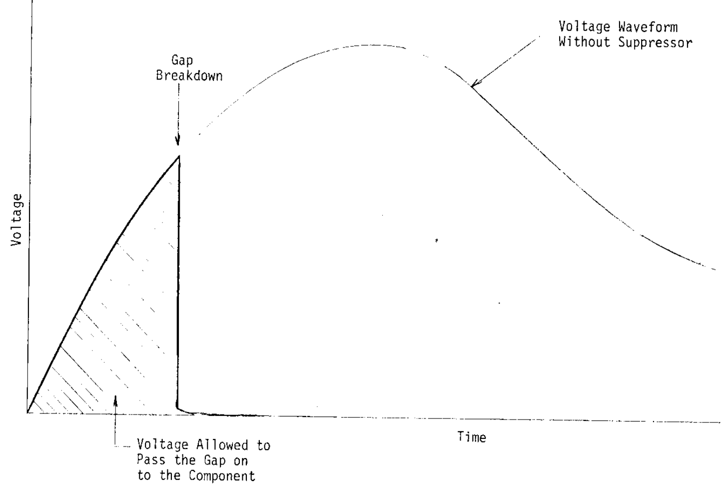
Transient suppressors which can be applied in the telephone plant are of two types: the spark-gap devices and the energy-absorber devices. Spark gaps have been used for a long time in the forms of the familiar carbon-block and the more modern gas tube. In both devices the gas (or air) between two electrodes connected to the line and ground breaks down when an overvoltage occurs. The level of voltage together with the speed at which this breakdown occurs is a characteristic of the design. After the breakdown, a low voltage is maintained across the gap, which allows a high current flow without large power dissipation (hence heating) in the device. Spark gaps have the limitation that the breakdown requires some time to occur; until then the transient is not limited. While the delay may be no longer than a microsecond or less, there may still be time for a fast-rising transient to destroy a component before the spark gap responds (Sketch).

Zener diodes, especially in their improved versions designed for transient suppression, and varistors (*vari*able nonlinear resis*tors*) are energy-absorber devices. In these the resistance of the device to the flow of current decreases as the current itself increases, a counteraction that produces a clamping effect on the voltage transient but that dissipates a large part of the transient energy within the device. Energy-absorber protectors do not have the delay limitation of spark gaps; they are permanently connected to the circuit and begin acting as the voltage rises, without waiting for a breakdown. Their limitation is the fact that the energy of the transient is dissipated in the source as well as in the device. The sharing of the energy is in inverse proportion to the impedance: for a given device, a low source impedance forces more of the energy to be dissipated in the device, which has a capacity limited by its dimensions (and dimensions are generally limited by cost and by available space).

Knowledge of the capability of suppressors to limit the voltage under defined conditions of overvoltage enables the equipment designer to build into his circuits the matching withstand capability. Survival is then assured. This is another key concept of TCL. *Equipment is designed to fit the protective level that practical suppressors can guarantee not to be exceeded rather than to retrofit suppressors after the equipment is found to have transient problems.* Of course this is an idealized situation because uncertainties of the environment, practical manufacturing tolerances, and the fundamental refusal of Nature to be coerced into neat human systems will still allow some failures to occur. But imperfect as the implementation of the TCL might be, it will still be better than to wait for the perfect system to come along.

The TCL approach is being proposed to the industry through the medium of engineering society meetings, technical papers, and standards committees. Engineers are receptive to the concept, for the standard test conditions will enable them to compare results and to evaluate performance under consistent conditions. While the concept has not yet been elevated to the status of an industry standard, acceptance is increasing.

An example of possible coordination for cost-effectiveness can be found in the power supplied for telephone electronics connected to the AC power grid. Typically, rectifiers in these supplies are exposed to all the transients occurring in the power system; for central locations these can be mild, but for line equipment in isolated locations exposure can be severe. Requiring the rectifiers to withstand the several thousand volts which can occur on the lines would force the designer to select expensive rectifier with high Peak Inverse Voltage ratings (PIV). (This PIV rating affects directly the price of the device.) It is much more effective to specify a rectifier with a PIV rating consistent with the normal voltages of the power circuit, at reasonable cost, and then to provide protection ahead of the rectifiers with a device whose cost is lower than the price differential between the high PIV rectifier and the low PIV rectifier.



Another example, a potentially long retrofit problem, will illustrate what can happen when coordination is not designed at the outset of a system. Telephone switching circuits using hybrid relay and semiconductor circuits are typically protected by gas tube primary protectors. A situation can develop where lack of coordination between the withstand capability of the components that immediately follow the protector and the clamping capability of the protector will cause failure of the component. One obvious "fix" is to increase the withstand capability of the component and make this increase a new specification. However, the failing component may in fact have acted, while failing, as a protector for the rest of the system, and raising its withstand level would let the transient go farther into the system, causing more extensive damages. What is needed is a systematic appraisal of the total capabilities and withstand levels—that is, a *control of the transient levels* allowed to occur in the system, starting with protectors installed where the lines enter the plant, possibly with additional protectors deeper into the system.

Protection for the more sensitive equipment being installed today is possible. Acceptance of the Transient Level Control concept throughout the electronics industry would enable telephone system manufacturers and operators to enjoy at reasonable cost a high degree of reliability. ■