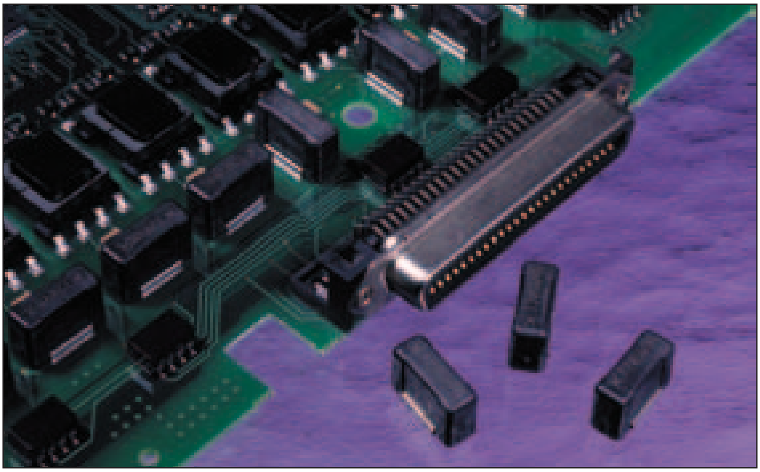
GR-1089: North America Network Equipment
Application Note

Modern public switched telephone network (PSTN) equipment frequently has an electronic interface to the network that is subject to the same overvoltage and overcurrent stresses that have plagued the telecommunications system since its inception. Legacy network equipment interfaces tolerated these overstresses well, but the electronic interface is much less robust.

While the objectives of network protection in the past were primarily to prevent injury and fire, the new network protection must also prevent damage. This note discusses the electrical overstresses to which telecommunications systems are exposed, the protection methods used to control the exposure, the Telcordia GR-1089 specification for Electromagnetic Compatibility and Electrical Safety (which governs the performance of the protectors), protective devices, and design considerations for communications network equipment in North America. Refer to the "ITU Recommendations" application note on page 76 for applications outside North America.



The Problem: Electrical Overstresses on the Telecommunications System

Overstresses in the form of overvoltage and overcurrent can occur in telecommunications systems due to lightning and through interaction with the AC power network. The Telcordia specification (formerly published by Bellcore) is based on many years of field experience and careful measurement of these overstresses.

Lightning surge is the most common source of overstresses. Currents may enter suspended cables by direct or indirect strike, or they may enter buried cable by the action of ground currents.

Since telephone cables very often share a pole or common-use trench and ground rod with the AC power system, some level of induced current is almost always measurable on the tip-and -ring conductors. When a fault occurs in the power system, these currents can become large. Three types of overstress occur on telecommunications circuits as a result of power system faults:

1. *Power cross* occurs when the power lines make electrical contact with the telephone circuit conductors. A power cross can drive large currents through the telephone cables.

2. *Power induction* occurs when neighboring power lines carry a heavy current due to a fault or switching transient.

3. *Ground potential rise* occurs when high currents due to a power fault or lightning surge to ground result in a significant potential difference between the point of the fault and the ultimate earth ground.

Overstresses also occur in two modes, longitudinal and metallic. *Longitudinal mode* refers to the case where the overstress is present between tip-and-ring and ground. Longitudinal overstresses are the more common type and occur during power induction or power crosses where both conductors have the same exposure to the hazard. Lightning-induced overstresses are also typically longitudinal in the absence of any imbalance resulting from terminating equipment.

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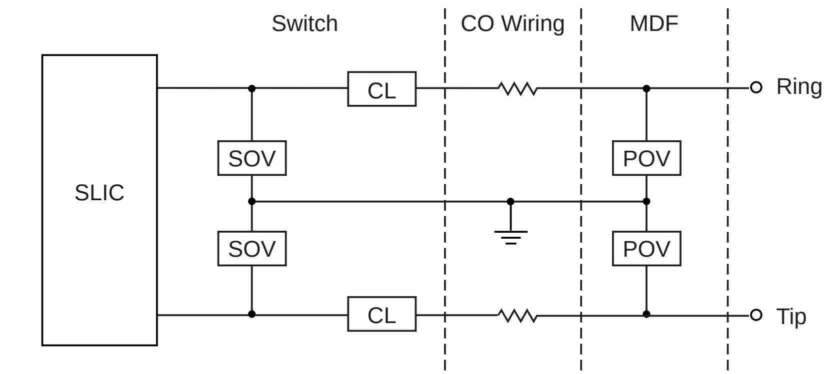
Figure 1. Simplified Model of Central Office End of Subscriber Loop



CL = Current limiting device
CO = Central office
MDF = Main distribution frame
POV = Primary overvoltage protecton device
SLIC = Subscriber line interface card
SOV = Secondary overvoltage protection device

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Metallic mode refers to the case where the overstress is present between tip-and-ring. Metallic overstresses can also be generally due to an imbalance in the network; for example, when a protector on one side of the line conducts, but the protector on the other side does not.

The Solution

Protection Methods

Line protection networks are traditionally split into primary, secondary, and sometimes tertiary components. Primary protectors have greater energy-handling capacity than secondary or tertiary protectors; however, the activation threshold for primary protection components is often less precise than for secondary protection components. Figure 1 is a simplified model of a conventional central office subscriber loop driven by an electronic interface. The figure shows the location of the various protection components.

Primary protection is the first level of protection from an overstress event occurring in the outside plant. Primary protection devices typically reside in the main distribution frame (MDF) for central office (CO) equipment, and at building entrances. Primary protection is intended to divert all overstresses above a loosely defined threshold away from the protected equipment and into a reliable earth ground. Primary protection is generally the property of the operating company, and specifications for primary protectors provide the minimum level of protection that the telephone company guarantees its customers. Primary protectors always contain overvoltage protection devices, and may contain overcurrent protection devices as well.

Secondary protection operates on the residual voltages and currents passed by the primary protection. Secondary protection devices are usually located on the equipment to be protected and are the responsibility of the equipment manufacturer. The requirements for secondary protection are determined by standards and the customer's expectations. Secondary protection was originally intended to prevent fire and injury due to shock, but is now also tasked with preventing damage. Secondary protection usually contains both overvoltage devices and current-limiting devices. Overvoltage protection is necessary to prevent damage to the equipment and shock hazards. Current-limiting devices are necessary to prevent damage to the wiring and the overvoltage devices; they also serve to coordinate the actions of the primary and secondary overvoltage devices, since the secondary protectors usually operate at a lower threshold than the primary protectors.

Table 1. GR-1089

Spec Type and Level	Primary Protection?	Waveform (µ sec, open circuit)	Voltage (V, open circuit)	Current (A, short circuit)	No. Hits	Test Results*
*Lightning***						
Level 1, Surge 1	No	10/1000	600	100	±25	A
Level 1, Surge 2	No	10/360	1,000	100	±25	A
Level 1, Surge 3	No	10/1000	1,000	100	±25	A
Level 1, Surge 4	No	2/10	2,500	500	±10	A
Level 1, Surge 5	No	10/360	1,000	25	±5	A
Level 2, Surge 1	No	2/10	5,000	500	±1	B

Spec Type and Level	Primary Protection?	Volts (Vrms) (open circuit)	Current (Arms) (short circuit)	Duration (seconds)	No. Hits	Test Results*
Power Induction						
Level 1, Test 1	No	50	0.33	15 min	1	A
Level 1, Test 2	No	100	0.17	15 min	1	A
Level 1, Test 3	No	600 max.	1 (at 600V)	1	60	A
Level 1, Test 4	Yes	1,000	1.00	1	60	A
Level 1, Test 6	No	600	0.50	30	2	A
Level 1, Test 7	No	440	2.20	2	5	A
Level 1, Test 8	No	600	3.00	1.1	5	A
Level 1, Test 9	Yes	1000	5.00	0.4	5	B
Level 2, Test 3	No	600	7.00	5	1	B
Level 2, Test 4	No	600 max.	2.2 (at 600V)	15 min	1	B
Power Contact						
Level 2, Test 1	No	120, 277	25.00	15 min	1	B
Level 2, Test 2	No	600	60.00	5	1	B

*A = Must continue to operate after test.

B = Must not cause fire.

**Additional lightning requrements with respect to protection coordination are specified in GR-1089 issue 3. These shall be effective in January 2006.

Notes:

1 = May apply either Surges 1, 2, 4, 5 or Surges 3, 4, 5.

2 = This test is to be done on 12 tip-and-ring pairs simultaneously.

3 = Run test at 200, 400, and 600Vrms, and just below OV protective device breakover voltage.

4 = Surge applied to tip-and-ring pair simultaneously.

Standards Governing PSTN Equipment: GR-1089

Based on the best available information, Telcordia has written the GR-1089 standard to control the overstresses that can appear on PSTN. Equipment passing tests in this standard can be expected to operate satisfactorily on the PSTN, even when subjected to the overstresses discussed previously. Table 1 shows some of the GR-1089 requirements.

Note: Telcordia Technologies, formerly Bellcore, now publishes the GR-1089 and other relevant documents.

Protective Devices

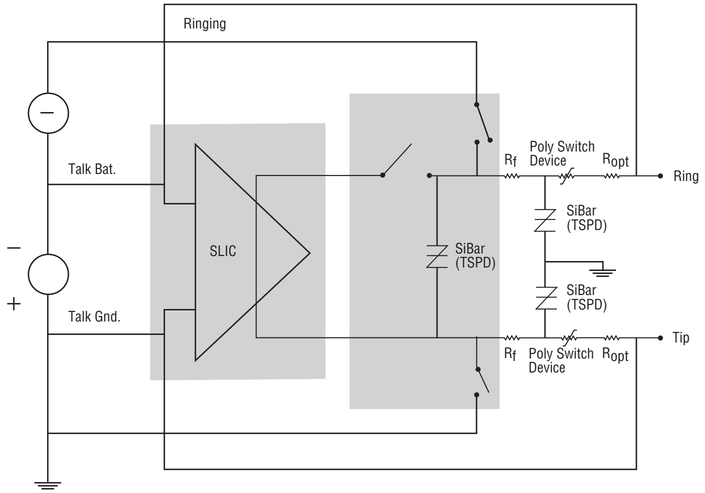
Protective devices are generally classed as current-limiting or voltage-limiting. *Current-limiting devices* are most important in protecting the equipment from long duration faults, during which joule heating can result in a fire hazard, or can damage thermally sensitive components. *Voltage-limiting devices* are intended to prevent dielectric breakdown of component or system insulation, which could cause high currents, arcing, and other potential hazards.

Current-limiting can be accomplished using a resistor, fuse, or PTC (positive temperature coefficient) device. Resistors are rarely an acceptable solution because an expensive high-power resistor is required. Specially designed fuses may be used; however, they are susceptible to nuisance tripping and must be replaced after operation. In addition, lightning robust fuses generally have a higher hold current than PTC devices, thereby letting through higher levels of fault current. The preferred solution is an active element, such as a PTC device, which has low resistance in normal operation and high resistance in fault states. These devices are self-resetting in that they return to normal operation after the fault has cleared and the power is removed from the circuit.

Overvoltage limiters can be either foldback devices or voltage clamping devices. Foldback devices switch to a very low impedance in the presence of an overvoltage event, diverting the fault current away from the protected circuit. Clamping devices pass only the current necessary to limit the voltage to the maximum allowed. Foldback devices are typified by thyristors, surge protector devices and gas discharge tubes. Clamping devices are commonly metal oxide varistors (MOVs) and avalanche diodes.

Figure 2. Simplified Example of a Line Card Design

(refer to Table 2 for recommended dévice solution)



The use of an optional resistance R_{opt}, and a current-sensing feedback resistor R_f, is explained in Telcordia GR-1089.

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Protection Design Example

Figure 2 illustrates a line-card design having an electronic network interface and on-board secondary protection. The interface is provided by a SLIC (subscriber line interface circuit) chip having an automatic line-balancing feature. The line-balancing feature requires a current-sensing resistance in tip-and-ring for operation.

The secondary protection consists of a series overcurrent limiter in both the tip and ring lines and secondary overvoltage-limiting device applied tip-to-ground and ring-to-ground. A third overvoltage device applied tip-to-ring is recommended in this application to provide improved protection from metallic surges.

PolySwitch TR600, TS600, or TSM600 devices have been designed to assist equipment designers in meeting the power induction and power cross requirements of GR-1089. SiBar TVBxxxSC thyristors have been designed to meet the lightning requirements of GR-1089 with no additional series impedance. The SC series thyristors are the preferred secondary overvoltage protection solution because of their high energy-handling capability, tight protection voltage specifications, low off-state power dissipation, low capacitance, and small size.

Telecom circuits can be protected by the combination of TSM600 PolySwitch devices and TVBxxxSC thyristors. No application resistance is needed (R_{opt}) to comply with all Telcordia GR-1089 requirements.

When designing with the PolySwitch TR600 or TS600 devices, an optional 10Ω, 2W resistor (labeled R_{opt} in Figure 2) is needed if the circuit is to be subjected to the GR-1089 Level 1, Surge 3 lightning test. However, the 10Ω resistor R_{opt} may be omitted if the Level 1, Surge 1 and Surge 2 tests are used as allowed by the specification. If the TSM600 device is used, the circuit can be subjected to the GR1089 Level 1, Surge 3, lightning test with no additional series resistance. The current-sensing resistance is the sum of all the resistances in the feedback loop, which in this case comprises the sum of R_f, and the resistance of the TR600, TS600, or TSM600 device. A typical value for the required current-sensing resistance is 100Ω.

Assuming the nominal resistance of the TR600-160 is 8Ω, the feedback resistor Rf in this example needs to be 92Ω.

Since R_f is protected by the secondary protector, it does not need to withstand the GR-1089 lightning impulses. Instead, it needs to withstand only the I^2t let-through of the current-limiting device. The use of PolySwitch devices typically results in lower I^2t let-through energies than when comparative fuses are used. Therefore, smaller, less expensive resistors can be used in these applications.

Table 2. Recommended Protection Devices for GR-1089 Requirements

Requirement	Poly Switch Overcurrent Device	Additional Resistance	Si Bar Overvoltage (TSPD)
Fully resettable	TSM600-250	None	TVBxxxSC
Fully resettable Level 1, Surge 1, 2, 4, 5	TR600-160 or TS600-200*	None	TVBxxxSB TVBxxxSC
Fully resettable Level 1, Surge 3, 4, 5	TR600-160 or TS600-200*	10Ω**	TVBxxxSB TVBxxxSC
Non-resettable overcurrent	FT600	0Ω	TVBxxxSC

* Low-resistance (–RA) and resistance-binned (–B-0.5) parts are available for applications where line balance is required.

** Recommended resistor: 10Ω, 2 watt, wirewound (Dale WSC-2 or equivalent).

Need for Coordinated Protection

The overcurrent protection device will protect the thyristor in case of power induction and power cross faults where the AC voltage exceeds the thyristor breakover voltage. GR-1089 tests such as Level 1, Test 3, and Test 4 are representative examples of such a situation. To prevent the thyristor from being damaged, it is important to coordinate the time-to-trip performance of the overcurrent protection device with the time-to-damage characteristic of the thyristor, ensuring that the overcurrent device reacts before the thyristor is damaged. Contact Raychem Circuit Protection if you require more detailed information on overcurrent and overvoltage device coordination.

When used in combination with other protective components, the TR600, TS600, TSM600, and TVB SiBar Thyristors series devices may be used to assist network equipment in meeting the protection requirements of GR-1089. Table 2 outlines some examples of how PolySwitch devices, fuses, resistors, and SiBar thyristors can be combined to meet Telcordia GR-1089 requirements.

Device Selection

The rated off-state operating voltage (V_{DM}) of the SiBar thyristor device must be greater than the system continuous operating voltage. This value is defined as the sum of the peak ringer (AC) voltage plus the DC battery voltage. Refer to SiBar Thyristor product section for more information.

PolySwitch TR600, TS600, and TSM600 devices may be obtained in low-resistance (–RA) and resistance-binned (–B-0.5) device ranges to achieve optimum tip-and-ring balance. See Section 4 or visit www.circuitprotection.com for more information on these options.