ITU-T Recommendations
Application Note

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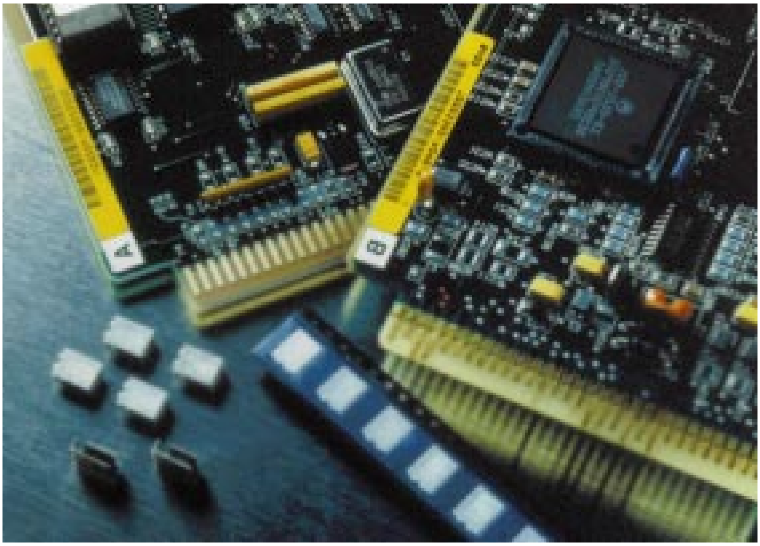


Telecommunication equipment has become ever more sensitive to overvoltage and overcurrent hazards on telephone lines. Conventional transformer-based architectures have been replaced by sensitive IC-based architectures. At the same time, the dependence on telecommunication systems and the increased competition between telecom operators has increased the need for highly reliable telecommunication network equipment with low maintenance costs.

Overvoltage and overcurrent hazards usually result from lightning, from transients induced by adjacent power lines, from direct contact with power lines, or from malfunctioning subscriber equipment. These hazards may destroy valuable network equipment and even cause injury to subscribers and maintenance personnel. The rising cost of advanced telecommunication system failure, the increase of unattended equipment in remote locations, and subscribers' high service expectations all make loss of a telephone line from overcurrent faults unacceptable. Consequently a number of telecom equipment manufacturers have turned to resettable protection devices, such as the PolySwitch device, and foldback devices, such as the SiBar device, in order to increase the reliability and safety of equipment and reduce the cost of maintenance.

The Problem

All network equipment is exposed to two types of electrical hazards.

The first hazard results from natural lightning strikes that can sometimes directly hit a network, though more often they induce high-voltage spikes in the pair of telephone wires. These spikes can damage sensitive electronic equipment at either end of the network, and therefore need to be shunted to ground by using overvoltage devices, such as SiBar devices.

The second hazard comes from induced AC power currents or from direct AC power contact. If the voltage of an overcurrent event is below the breakover voltage of the overvoltage protection, the result is continuous current into the equipment, which can damage downstream electronic components. On the other hand, when the voltage of the overcurrent fault is higher than the breakover voltage of the overvoltage protection device, then the overvoltage device itself needs to be protected from prolonged exposure to high current. A PolySwitch overcurrent protection device used in conjunction with a SiBar device can provide protection against both events.

Industry Recommendations: ITU-T

In most of the world, network switching and transmission equipment manufacturers must meet requirements, such as those recommended by the ITU-T, formerly CCITT. The ITU-T issues publications and recommendations on the protection of telecommunication equipment. The most relevant ITU-T recommendations are listed in Table 6. Recommendation K.20, relating to telephone exchanges and similar switching centers is summarized in Table 1 and Figures 1a, 1b, 1c, 2 and 3.

Table 1. Summary ITU-T K.20

No.	Test	Between	Test circuit	Maximum test voltage and duration	Number of tests	Agreed primary protection	Acceptance criterion (Note 1)
1a)	Lightning surge simulation	A and E with B earthed	Figure 1 a)	$U_{c(max)}$ = 1 kV	10	None	A
		B and E with A earthed	Figure 1 a)	$U_{c(max)}$ = 1 kV	10	None	
		A+B and E	Figure 1 b)	$U_{c(max)}$ = 1 kV	10	None	
1b)	Lightning surge simulation	A and E with B earthed	Figure 1 a)	$U_{c(max)}$ = 4 kV	10	Yes	A
		B and E with A earthed	Figure 1 a)	$U_{c(max)}$ = 4 kV	10	Yes	
		A + B and E	Figure 1 b)	$U_{c(max)}$ = 4 kV	10	Yes	
1c)	Simultaneous surge simulation on a group of n line ports	n x (A + B) and E	Figure 1 c)	$U_{c(max)}$ = 1 kV	10	None	A
2a)	Power induction	A+B and E	Figure 2	$U_{a.c.(max)r.m.s.}$= 600 V 0.2s	5	None	A
2b)	Power induction	A+B and E	Figure 2	$U_{a.c.(max)r.m.s.}$= 600 V 1s (Note 2)	5	Yes	A
3)	Power contact	A+B and E	Figure 3 Tests are made with S in each position	$U_{a.c.(max)r.m.s.}$= 230 V 15 min	1 for each position of S	None	B

Note 1: A = No damage or other disturbance.
B = No fire hazards may occur; any damage or malfunction should be confined to a limited number of lines.

Note 2: Condition might be adapted so that $I^2t = 1A^2s$.

The ITU-T distinguishes between unexposed and exposed areas. Unexposed areas have low lightning activity and relatively low soil resistivity. Cities often are classified as unexposed areas. All other environments are classified as exposed areas (mainly rural areas). The equipment is usually expected to operate satisfactorily in both environments, therefore it is tested under all conditions in Table 1. The test conditions with agreed primary protection simulate proper functioning in the more severe environments. Recommendation K.21 deals with subscribers' terminals and assumes that line protectors are fitted externally to the equipment in exposed areas. It is summarized in Table 2.

Figure 1a

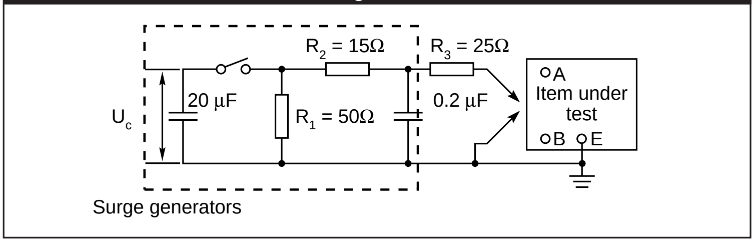


Figure 1b

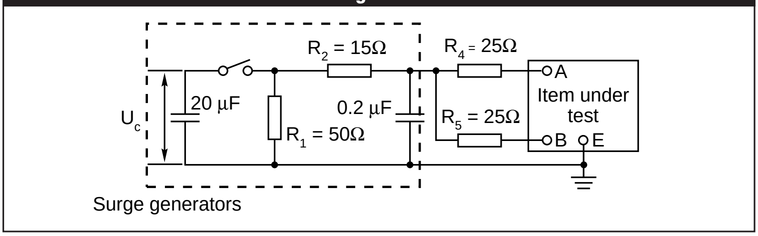


Figure 1c

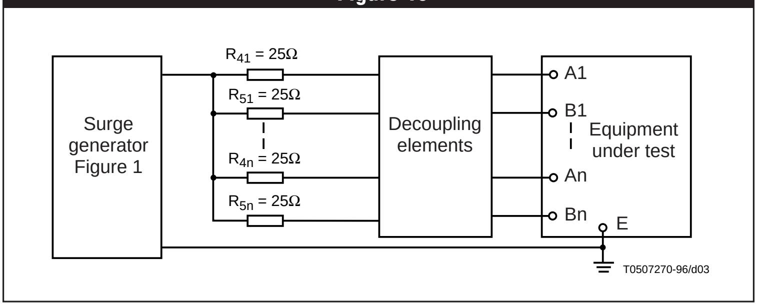


Figure 2

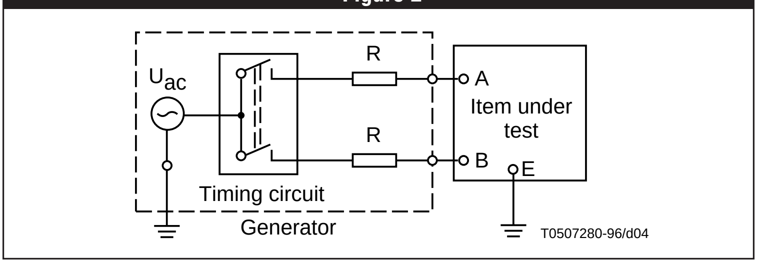
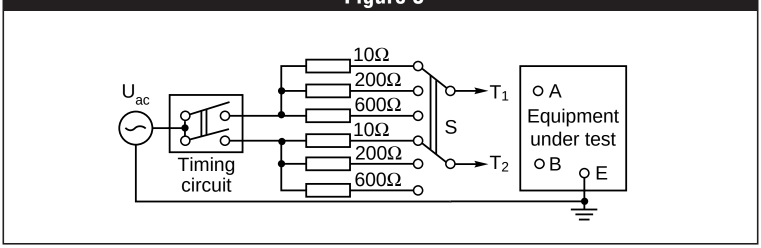


Figure 3



Overcurrent Solution

PolySwitch overcurrent protection devices are positive temperature coefficient (PTC) devices that act like resettable fuses to protect sensitive telecommunications network equipment from overcurrent faults. When an overcurrent fault occurs, the resistance of the TR250 or TS250 PolySwitch device increases from a 0.8 Ω to 14 Ω base resistance to a much higher resistance, effectively isolating the fault. In its high-resistance state the surface temperature of the device will be approximately 120°C. A small trickle current will maintain the PolySwitch device in its high-resistance state, dissipating little power. Once the fault condition and power are removed, the PolySwitch device—unlike a fuse—will reset, so normal telephone operation can resume.

Fast Tripping

At currents between 200 and 350 mA, TR250 and TS250 PolySwitch devices will trip before damage to the line interface can occur. PolySwitch devices, however, are not tripped by lightning-induced transients. Most alternate solutions, like fuses, that are lightning robust will not trip until an overcurrent fault of more than 500 mA exists, allowing a much larger current to pass into the subscriber line interface card (SLIC). This higher level can damage telecommunication equipment.

TR250 and TS250 PolySwitch devices typically trip faster than ceramic PTC devices, allowing downstream electronic components such as secondary

Table 2. Summary ITU-T K.21

No.	Test	Terminal connections	Test circuit	Maximum test voltage and duration	Number of tests	Added primary	Acceptance criterion
1a	Lightning surge simulation	T1 and A T2 and B	Figure 1 b	$U_{c(max)}$ = 1.5 kV	10	None	A
				$U_{c(max)}$ = 4 kV	10	Yes	A
1b		T1 and A, B, etc. in turn, T3 and all other terminals (see Note 1)	Figure 1 b	$U_{c(max)}$ = 1.0 kV	10	None	A
				$U_{c(max)}$ = 4 kV	10	Yes	A
1c	Simultaneous lightning surge simulation	n x (A + B) and E	Figure 1 c	$U_{c(max)}$ = 1.5 kV	10	None	A
2a	Power induction	T1 and A T2 and B	Figure 2	$U_{a.c.(max)r.m.s.}$ = 600 V 0.2 s	5	None	A
			Figure 2	$U_{a.c.(max)r.m.s.}$ = 600 V 1s (see notes 2 and 6)	5	Yes	A
2b		T1 and A, B, etc. in turn T3 and all other terminals (see Note 1)	Figure 2 Figure 2	$U_{a.c.(max)r.m.s.}$ = 600 V 0.2s $U_{a.c.(max)r.m.s.}$ = 600 V 1s (see Notes 2 and 6)	5 5	None Yes	A A
3a	Power contact	T1 and A T2 and B	Figure 3 Tests made with S in each position (see Notes 2 and 6)	$U_{a.c.(max)r.m.s.}$ = 230 V 15 min (see Note 5)	1 for each position of S	None	B
3b		T1 and A, B, etc. in turn T3 and all other terminals (see Note 1)	Figure 3 Tests made with S in each position (see Notes 3 and 4)	$U_{a.c.(max)r.m.s.}$ = 230 V 15 min (see Note 5)	1 for each position of S	None	B

Note 1: An earthed connection may prevent the establishment of normal conditions when the test is made. In these cases alternative testing procedures should be followed to meet the requirements of this test (for example a low voltage spark-gap or other variation in the earth connection should be used).

Note 2: The rationale for the test voltage and duration values is given in annex A.2 of Recommendation K.20.

Note 3: Fuses, fuse cables, etc. may be left in circuit during these tests.

Note 4: If the switch S is in the position 10 Ω, the current may be limited to lower values according to national regulations.

Note 5: The value of $U_{a.c.(max)}$ shall be varied according to the local mains voltage.

Note 6: Condition might be adapted so that $I^2t = 1A^2s$.

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Table 4. Summary of field studies showing 50/60-Hz AC overcurrent faults

Study location (author)	Frequency of 50/60-Hz faults	Characteristics of faults
Canada (Bell Canada)	2.5% of all lines studied	Average voltage: 300 V
USA (AT&T)		Average voltage: 371 V; average current: 2.71 A
USA (BellSouth)	6.5% of all lines studied	Average voltage: 300 V
Italy (SIP)		Average voltage: 430 V; average current: 2.35 A

Figure 4: Typical Protection System for Network Equipment

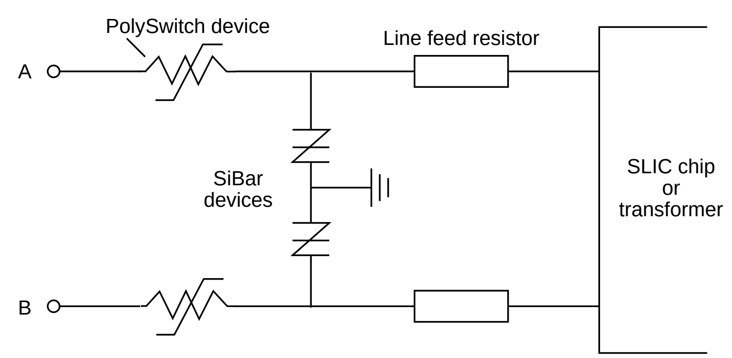
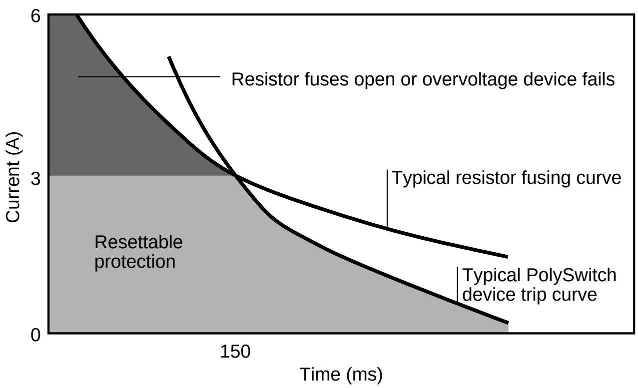


Figure 5: Typical PolySwitch Device/Line Feed Resistor Response to Overcurrent Faults



overvoltage devices and resistors to be sized smaller.

Small Size

PolySwitch devices are typically smaller than ceramic PTC devices. Furthermore, they can be supplied as surface-mount devices to fit the stringent space requirements of new miniaturized electronic boards.

Overvoltage Solution

SiBar overvoltage protectors are foldback devices which have a current voltage curve much like that shown in Figure 6. The device is normally in a “high resistance” state for voltages below the breakover voltage. In this state very little current flows through the device when voltage is across the device. When the voltage exceeds the breakover voltage, the device “foldsback” creating a low-impedance path and effectively shorting out the overvoltage condition. The device will remain in this low-impedance state until the current through the device is decreased below I_{hold}. SiBar devices are designed so that the I_{hold} of the device is typically >200 mA and is above the maximum loop current in the telecom system. Thus, after an overvoltage event has passed, the device can reset to its high- impedance state and allow normal system operation to occur.

For a given fault current, the power dissipated is much smaller than a clamp device such as a metal oxide varistor or an avalanche diode, since the voltage across the foldback device will be smaller. This

Figure 6: Current-Voltage Curve of a SiBar Foldback Device

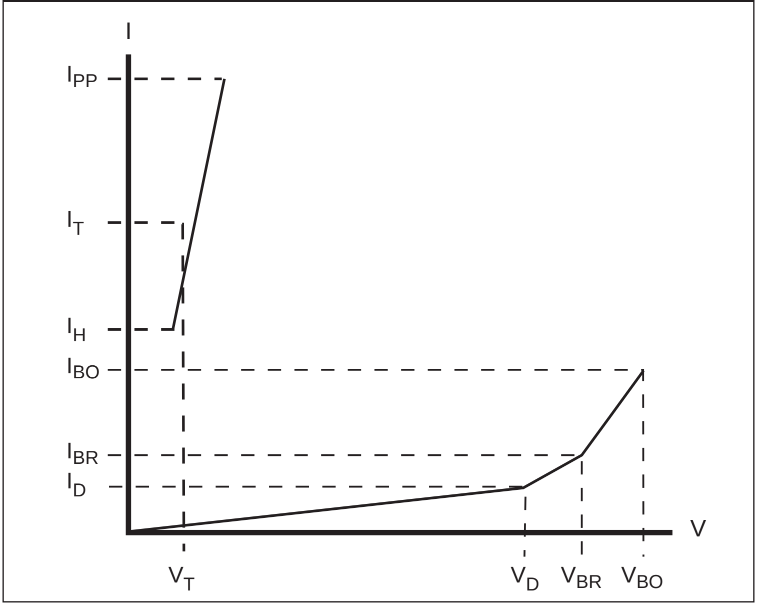


Table 5. TR250 and TS250 series for ITU-T requirements

Device	I_{hold} (mA)	Resistance (Ω)	Typical trip time at 1 A (s)
TGC250-120T	120	8.0–13.0	1.2
TR250-120	120	4.0–8.0	1.5
TR250-120T	120	6.0–10.5	0.6
TS250-130	130	6.5–12.0	1.5
TR250-145	145	3.0–6.0	2.0
TR250-180U	180	0.8–2.0	10.5

allows the device to be much smaller. The smaller size results in lower capacitance which is highly desirable for higher speed communication equipment. Being a silicon-based device allows the breakover voltage to be accurately set and it will not degrade after multiple fault events. The SiBar devices are supplied in a SMB surface-mount package to meet the space requirements of miniaturized electronic boards.

Application

Figure 4 displays a typical protection system employed by network equipment manufacturers in order to comply with ITU-T K.20 requirements. The SiBar device protects the sensitive electronics from fast overvoltage events, including lightning transients. The line feed resistor serves the purpose of feeding current to the telephone. The TR250 or TS250 PolySwitch devices provide current limiting that may be required during power contact events that have a voltage lower than the foldback voltage of the SiBar device. Additionally, the base resistance of the PolySwitch device limits the current during events that exceed the foldback voltage of the SiBar device, thus enabling the SiBar device to survive.

PolySwitch Device Benefits

When a PolySwitch device is installed in the circuit it provides two important advantages. First, it protects the line feed resistors from overheating. Without a PolySwitch device, during AC sneak current events (that is, currents in the 200 mA to 1 A range), these resistors do not fuse open. They typically overheat and can completely destroy the circuit board. If a PolySwitch device is installed, it limits the sneak current and prevents overheating of the line feed resistor.

Second, network equipment manufacturers and network operators have to provide a highly reliable telecommunication service, with minimal loss of system availability, and minimal maintenance costs. If non-resettable overcurrent protection is used, even after the overcurrent fault is cleared, the circuit will be out of service, and a service technician will have to be dispatched to change the line card or subscriber's terminal. However, with a PolySwitch resettable device, the circuit will reset and telephone service will resume without need for repair or a service call.

The most probable range of overcurrent hazards as measured in field studies is shown in Table 4. Typical currents measured are from 350 mA up to 2.71 A. Figure 5

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Table 6. Most important ITU-T publications

Directives concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines. Vol. VIII. Protective Devices. Geneva 1996.
Recommendation K.11 Principles of protection against overvoltages and overcurrents.
Recommendation K.12 Characteristics of gas discharge tubes for the protection of telecommunications installations.
Recommendation K.20 Resistibility of telecommunication switching equipment to overvoltages and overcurrents.
Recommendation K.21 Resistibility of subscribers' terminals to overvoltages and overcurrents.
Recommendation K.28 Characteristics of semi-conductor arrestor assemblies for the protection of telecommunications installations.
Recommendation K.30 Characteristics of self-restoring current-limiting devices.
Recommendation K.36 Selection of protective devices.

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shows the typical response of a line feed resistor and overvoltage device combined with a PolySwitch overcurrent protection device. In a range up to 3 amps, PolySwitch devices offer the benefit of a fully resettable protection system. For network operators and their subscribers this minimizes service calls, increases system availability, and reduces maintenance cost.

Device Selection

As described in Figure 4, use of the PolySwitch device requires coordinated design between the line feed resistor, the secondary overvoltage protection device, and the SLIC circuit. Please refer to TS and TR product line data for specific information on resistance, switching speed, dimensions, current, and voltage rating. Please refer to the TVB data section for specific information on SiBar devices.

Table 5 shows the most important characteristics of the TR250 and TS250 devices. TVBXXX-050 devices are rated at 50 A under a 10/1000-µs waveform. The device rating exceeds all surge currents obtainable under ITU K.20 and K.21 lightning test without primary protection in place. When a primary protector is in place, sufficient line impedance (resistance and/or inductance) must be in place between the primary overvoltage protector and the secondary overvoltage protector to ensure that the primary protector operates under the lightning test because the PolySwitch devices and SiBar devices are not designed for lightning surge currents achievable under these tests.

SiBar devices used in conjunction with TR250 and TS250 devices will assist the designer in meeting the power induction and power contact test conditions specified by ITU K.20 and K.21. The appropriate PolySwitch device and SiBar device must be evaluated and tested for each application. The most important ITU-T publications are listed in Table 6.

Hundreds of Millions of Lines Protected

PolySwitch devices are in use all over the world, as resettable overcurrent protection elements in central office switching equipment, digital loop carriers, primary protection modules, subscriber protection equipment, PBXs, and subscriber equipment. A number of newer technologies—such as ADSL, T1 repeaters, ISDN, and others—have also included PolySwitch resettable fuse protection.

Raychem's new SiBar devices are designed to assist in meeting the overvoltage requirements of ITU K.20 and K.21 and can be used in secondary applications where PolySwitch devices are currently being used. Please refer to the TVB product line data for information and check with your local Raychem representative as new products will be available in the future.