AN2064
APPLICATION NOTE

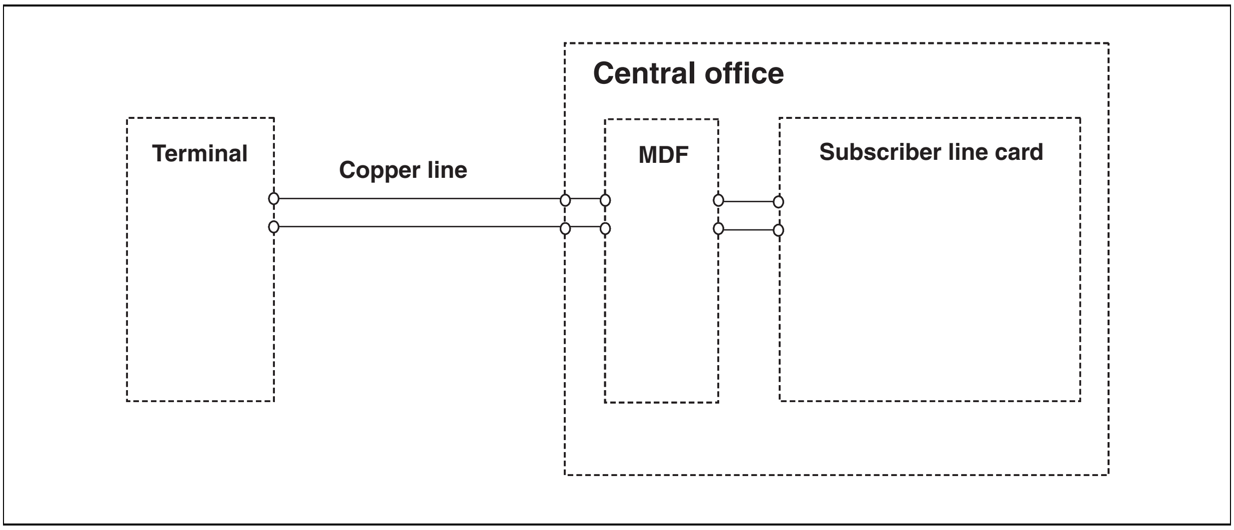
Compliance of series/parallel protections for Telecom CO

ST and Cooper Bussmann, experts of wireline networks protection, have jointly prepared this application note to present a full protection solution based on companion devices from both companies.

Even with all the wireless telecommunication options (GSM, DCS, PCS, UMTS, Wi-Fi, etc…), the wireline network remains the most cost effective wide range solution to exchange data over the world. The use of this copper carrier requires system designers to provide adequate protection against overvoltage and overcurrent events occurring on the line. The goal of this document is to provide telecom system card designers the necessary information to make proper protection choices.

An example of a wireline telecom network is shown in figure 1. Two different kinds of equipment are connected together by means of a copper line. One line termination is connected to the Central Office (CO) while the other is connected to the terminal. In the CO, the line goes through the Main Distribution Frame (MDF), which connects network to the signal cabinet, and is then connected to a subscriber line card.

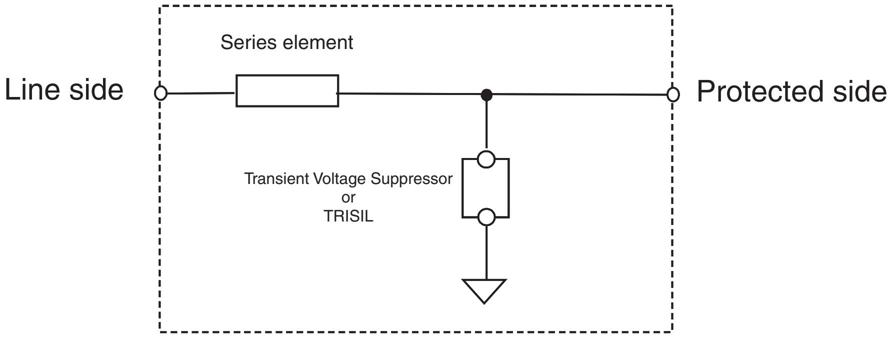
Figure 1: Classical topology of wireline network subscriber line card



The following pages show how to implement the protection stage utilizing series overcurrent protection devices and Transient Voltage Suppressor (TRISIL™) devices (figure 2). Both elements work together during surges, TRISIL acts to suppress overvoltages while the series overcurrent devices protect the circuit from lethal overcurrents.

TM: TRISIL is a trademark of STMicroelectronics.

Figure 2: One wire telecom protection topology



1. TRISIL™ selection

Transient voltage suppressor (TRISIL) selection has to take into account the two working modes it will meet during its life. The first mode is the normal operating mode where the protection device has to be transparent, that means no impact on the speech or data signal. The second mode is the suppression mode where the TRISIL has to eliminate all dangerous transient voltage surges.

During normal operation, we have to focus on voltages and currents managed in the line. These values depend on the specific countries where equipment is located and the type of signal being managed (analog or digital). For example, in the US the nominal battery voltage is -56.6V and the ringing voltage is $150V_{RMS}$, where the normal operating voltage is between 0V and -56.6V in speech or dialing mode and between +155.5V and -268.7V in ringing mode. In digital networks the voltages can be the same as those used in analog networks, as is the case with ADSL. Frequently, ringing is managed by digital code where only the battery voltage is present (generally -100V), as is the case in ISDN applications. When the telephone is picked up, the loop current increases and indicates to the CO to stop the ring signal or to wait for dialing signals. Call connection occurs when the loop current exceeds a few milliamps. Analog CO systems may use series resistors while digital systems do not. These resistors (10Ω to 100Ω depending on the applicable country standard) are used to manage line longitudinal balancing while the use of any series resistance is forbidden in ADSL system. From these requirements we can conclude that the TRISIL threshold voltage has to be higher than 268.8V for US analog and ADSL networks (190V for Europe) while the TRISIL leakage current has to be lower than 1mA. The right choice for US is 270V (200V for Europe) and the leakage current is less than a few µA.

When considering the suppression mode, we have to take into account that telecommunication lines can be subjected mainly to two kinds of disturbances. The first disturbance is linked to atmospheric effects while the second disturbance is produced by contact or proximity with the 50/60Hz mains network. These disturbances are well defined in standards, which can be worldwide or dedicated to a specific country.

The table 1 gives the main lightning standards.

Table 1: Main line card lightning surge standards

Country	Standard	Surge voltage	Waveform	Current
Worldwide	ITU-T K20	1500V	10/700µs	37.5A
Worldwide	IEC-61000-4-5	1000/4000V	10/700µs	25/100A
Worldwide	IEC-61000-4-5	1000/4000V	1.2/50µs	25/100A
Germany	VDE0433	2000V	10/700µs	50A
Germany	VDE0878	2000V	1.2/50µs	50A
USA	GR-1089 Core (Telcordia)	2500V	2/10µs	500A
USA	GR-1089 Core (Telcordia)	1000V	10/1000µs	100A
France	I3124	1000V	0.5/700µs	25A

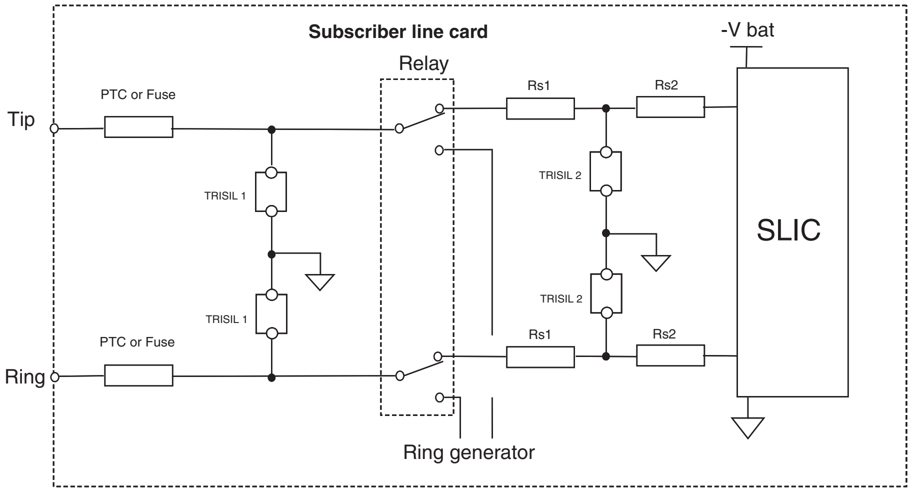
Main worldwide standards for 50/60Hz overvoltage disturbances can be defined by two parameters: the applied RMS voltage, between 60V and 1000V, and the test duration, between 0.2s and 15min.

From this section we can conclude that the TRISIL current capability must be adapted according to the specific country (for example, a waveform surge of 100A for 10/1000µs for the US). As TRISIL are dedicated to manage high currents for short duration surges (in the range of hundreds of ms) the 50/60Hz disturbances test requirements show the need of a complementary protection stage, implemented with series protection devices like fuses or positive temperature coefficient resistors (PTC).

2. Protection circuit

In the protection circuit we find particularities linked to the characteristics already mentioned in the TRISIL selection section and also linked to the CO line interface. Generally the subscriber line interface circuit (SLIC) is directly connected to the line without any isolation stage when operating in analog mode, while in digital applications isolation is achieved using a transformer. Please note that, at the CO side, protection is split into two areas - the primary protection stage located in the MDF and the secondary protection directly soldered on the subscriber line card.

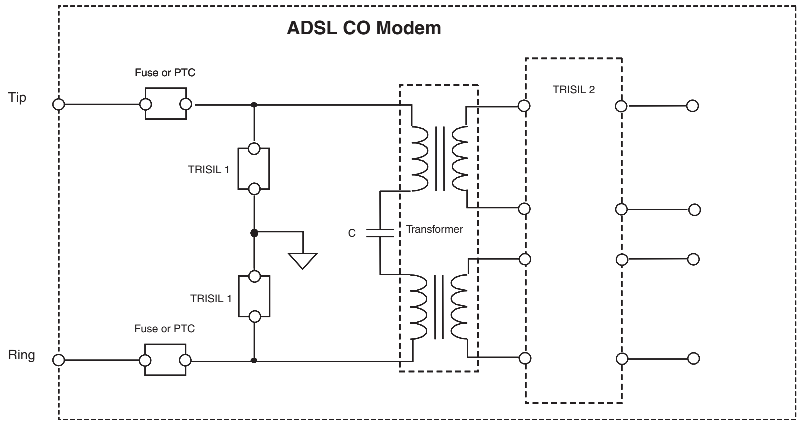
Figure 3: Analog line card protection circuit



Secondary protection, first stage Fuse or PTC and TRISIL 1, second stage TRISIL 2

Figure 3 shows the classical protection topology used to protect one section of an analog subscriber line card. A first stage uses both series overcurrent protection devices (fuses or PTCs) and TRISIL protectors (TRISIL 1, threshold voltage = +/- 270V for US) allowing the ring relay to be protected against full lightning and power contact surges. A second level (TRISIL 2, threshold voltage = 0/-Vbat) allows the SLIC to be fine tuned protected. The presence of longitudinal series resistors makes the current capability rate of this TRISIL to be adjusted.

Figure 4: CO ADSL modem protection circuit



Secondary protection Fuse or PTC and TRANSIL 1

Figure 4 shows the protection topology generally used to protect the ADSL modem (or line cards when use of a line transformer). This modem is connected to the analog line card by means of a splitter stage and then receives the same operating voltages. Please note that series resistors are generally not permitted in such an application. Protection is provided by the TRISIL (TRISIL 1, threshold voltage = +/- 270V), which assumes the full lightning current while the series overcurrent protection devices (fuses or PTCs) allow the module to be well protected against 50/60Hz power contact.

3. Series protection

As previously mentioned, the use of series overcurrent protection devices is mandatory to protect subscriber line cards against 50/60Hz power contacts. As far as power contact is concerned, standards require the equipment to withstand several tests with different acceptance criteria. First level criterion for US standards (or A criterion for European requirements) requires the equipment to be fully operational after tests while second level (or B criterion) allows the system to be out of order but no fire or smoke is permitted. Table 2 shows AC power fault requirements of the US Telcordia GR1089 standard.

Table 2: Telcordia GR1089 AC power fault test

Test	Applied Voltage, 60Hz	Short Circuit Current	Duration
First Level AC Power Fault Test			
1	$50V_{RMS}$	0.33A	15 minutes
2	$100V_{RMS}$	0.17A	15 minutes
3	$200V_{RMS}$, $400V_{RMS}$, $600V_{RMS}$	1A at 600V	60 Applications, 1 second each
4 (*)	$1000V_{RMS}$	1A	60 Applications, 1 second each
5	NA	NA	60 Applications, 5 second each
6	$600V_{RMS}$	0.5A	30 seconds each
7	$440V_{RMS}$	2.2A	5 x 2 seconds each
8	$600V_{RMS}$	3A	5 x 1.1 second each
9 (*)	$1000V_{RMS}$	5A	0.5 second each
Second Level AC Power Fault Test			
1	$120V_{RMS}$, $277V_{RMS}$	25A	15 minutes
2	$600V_{RMS}$	60A	5 seconds
3	$600V_{RMS}$	7A	5 seconds
4	$100V_{RMS}$-$600V_{RMS}$	2.2A at 600V	15 minutes

(*) Primary protector in place (MDF)

Using series overcurrent protection, two technologies are available, PTCs and fuses.
PTCs are resistive elements that dissipate power when subjected to current, increasing their temperature and making their resistance quickly increase (10Ω @ 25°C and 100kΩ @ 150°C for example). The nice feature of the PTCs is that they are resettable but they have two main drawbacks. The first drawback is its resistance and, as already mentioned, some applications like digital networks do not allow resistive elements. The second drawback is linked to its tolerance, which makes it difficult to achieve line equilibrium (longitudinal balancing).

Fuses do not have these resistive drawbacks, making them well suited for digital applications.

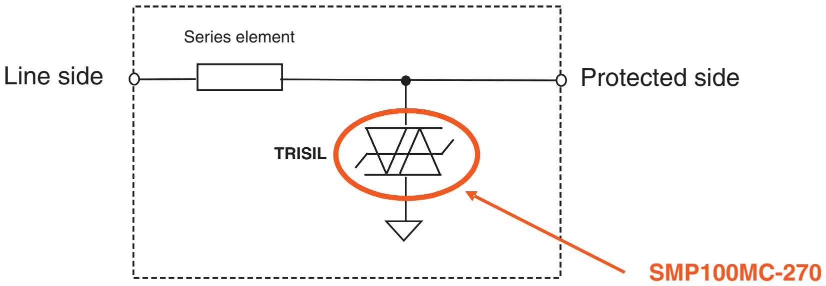
From the previous discussion we can conclude that the fuse must withstand first level surges for US (or A criterion for Europe) but may operate for second level surge (or B criterion). As far as the US market is concerned the fuse has to remain operational for the 10/1000µs 1kV 100A and the 2/10µs 2.5kV 500A lightning surges. It must also withstand first level AC power faults while it must operate for $277V_{RMS}$ 25A and $600V_{RMS}$ 60A second level AC power faults.

4. Example of series / TRISIL protection combination

For this example we will focus on US market applications where low series resistance is an issue. As mentioned earlier, TRISIL characteristics are the following:

. Minimum breakdown voltage	> 270V
. Maximum leakage current	< few µA
. Current capability	> 100A 10/1000µs
. Current capability	> 500A 2/10µs

Figure 5: TRISIL choice



The TRISIL which respects these requirements is the SMP100MC-270 from STMicroelectronics (see figure 5).

Table 3: SMP100MC series datasheet electrical parameters from STMicroelectronics

Types	I_{RM} @ V_{RM} max.		I_R @ V_R max. note1		Dynamic V_{BO} max. note 2	Static V_{BO} @ I_{BO} max. max. note 3		I_H min. note 4	C typ. note 5	C typ. note 6
	µA	V	µA	V	V	V	mA	mA	pF	pF
SMP100MC-120*	2	108	5	120	155	150	800	150	25	50
SMP100MC-140*		126		140	180	175			25	50
SMP100MC-160		144		160	205	200			25	50
SMP100MC-200		180		200	255	250			20	45
SMP100MC-230		207		230	295	285			20	40
SMP100MC-270	2	243	5	270	345	335	800	150	20	40

Note 1: I_R measured at V_R guarantee V_{BR} min ≥ VR
Note 2: see functional test circuit 1
Note 3: see test circuit 2
Note 4: see functional holding current test circuit 3
Note 5: V_R = 50V bias, V_{RMS}=1V, F=1MHz
Note 6: V_R = 2V bias, V_{RMS}=1V, F=1MHz

* in development

Table 4: SMP100MC series datasheet absolute ratings (T_{amb} = 25°C)

Symbol	Parameter		Value	Unit
I_{PP}	Repetitive peak pulse current	10/1000 µs	100	A
		8/20 µs	400	
		10/560 µs	140	
		5/310 µs	150	
		10/160 µs	200	
		1/20 µs	400	
		2/10 µs	500	
I_{FS}	Fail-safe mode : maximum current (note 1)	8/20 µs	5	kA
I_{TSM}	Non repetitive surge peak on-state current (sinusoidal)	t = 0.2 s	18	A
		t = 1 s	9	
		t = 2 s	7	
		t = 15 mn	4	
I^2t	I^2t value for fusing	t = 16.6 ms	20	A^2s
		t = 20 ms	21	
T_{stg}	Storage temperature range		-55 to 150	°C
T_j	Maximum junction temperature		150	
T_L	Maximum lead temperature for soldering during 10 s.		260	°C

Note 1: in fail safe mode, the device acts as a short circuit

Tables 3 and 4 show that the SMP100MC-270 complies with the CO US market standard requirements. The telecom system design engineer must next define the suitable fuse. Figure 6 gives the surge capability limit of the SMP100MC series TRISIL when submitted to the power fault disturbances. The series overcurrent protection device cannot be a PTC due to its high resistance value, so the only choice will be the fuse, which meets the following criteria:

. Shall not operate for 100A 10/1000µs surge
. Shall not operate for 500A 2/10µs surge
. Shall operate for 25A_{RMS} (35.4A peak) within 40ms (see SMP100MC series I_{TSM} curve figure 6)
. Shall operate for 60A_{RMS} (85A peak) within 4ms (estimated value)

Figure 6: I_{TSM} and I_{RMS} capability versus surge duration

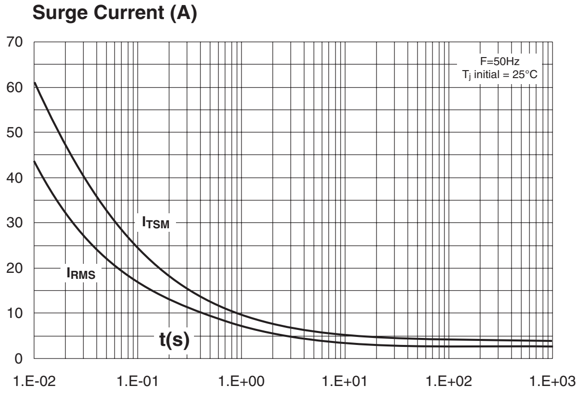


Figure 7: Fuse choice

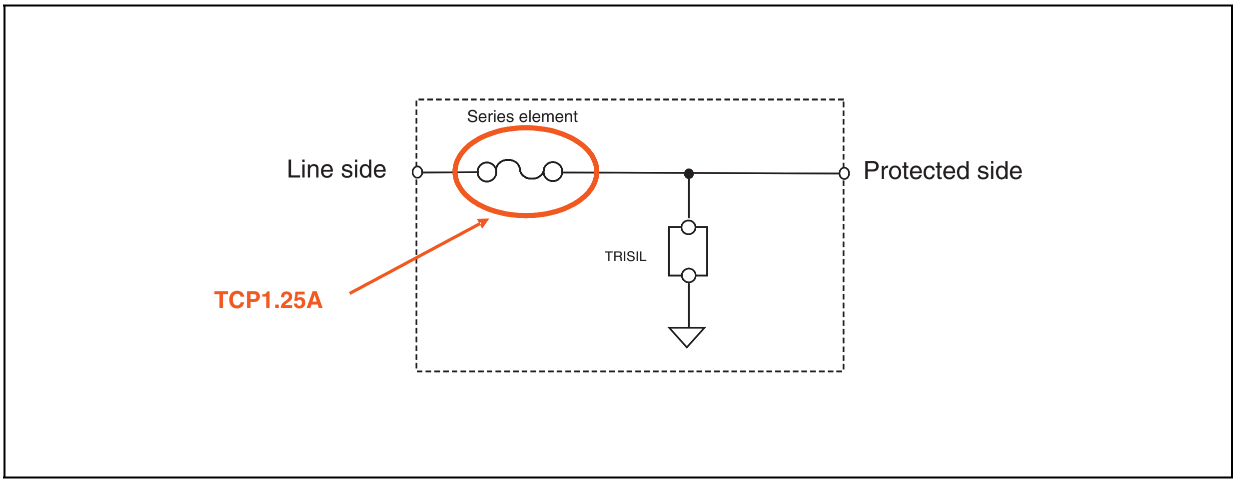


Table 5 gives data about the TCP fuse series from Cooper Bussmann. The TCP1.25A fulfills the Telcordia 10/1000µs and 2/10µs lightning test requirements and the interrupting capabilities with respect to the 25A and the 60A power cross requests requested by this standard (see figure 7).

Table 5: TCP series datasheet lightning and power cross specification from Cooper Bussmann

LIGHTNING SURGE SPECIFICATIONS						
Surge Specification	**Surge**	**Repetitions**	**Waveform (µSec.)**	**Current (A)**	**Voltage (V)**	**Performance Requirement**
TCP 500mA tested						
FCC 47 Part 68	Longitudinal Type B	2	5x320	37.5	N/A	Fuse cannot open
FCC 47 Part 68	Metallic Type A	2	10x560	100	800	Fuse must open safely
Surge out		25	10x160	65	N/A	Fuse cannot open
TCP 1.25A and TCP2A tested						
FCC 47 Part 68	Longitudinal Type A	2	10x160	100 per fuse	1500	Fuse cannot open
FCC 47 Part 68	Metallic Type B	2	10x560	100	800	Fuse cannot open
Bellcore GR-1089-CORE	First Level Lightning	50	10x1000	100	1000	Fuse cannot open
Bellcore GR-1089-CORE	First Level Lightning	50	2x10	500	2500	Fuse cannot open
Surge out		1	10x160	160	N/A	Fuse cannot open
Surge out		1	10x560	115	N/A	Fuse cannot open

ELECTRICAL AND POWER CROSS SPECIFICATIONS											
Product Code	**Voltage Rating AC**	**Interrupting Rating***		**DC Cold**			**Typical Melting I^{2}t†**	**Maximum Total Clearing**	**Typical Voltage Drop‡**	**Alpha Code Marking**	
		250VAC	**600VAC**	**Resistance** (ohms)**						**1st Code**	**2nd Code**
				min.	**typ.**	**max.**					
TCP500mA	250 V	50 A	40 A	0.420	0.530	0.640	1.3 A^{2}s	100 A^{2}s	471mV	F	
TCP1.25A	250 V	50 A	60 A	0.070	0.090	0.110	22.2 A^{2}s	100 A^{2}s	150mV	J	R***
TCP2A	250 V	50 A	60 A	0.050	0.075	0.100	30 A^{2}s	100 A^{2}s	205mV	N	

* AC Interrupting Rating (Measured at designated voltage, 100% power factor)

** DC Cold Resistance (Measured at 10% of rated current)

*** On RoHS Compliant Version (-R option)

† Typical Melting I^{2}t (Measured with a battery bank at 60V DC, 10x-rated current, time constant of calibrated circuit less than 50 microseconds)

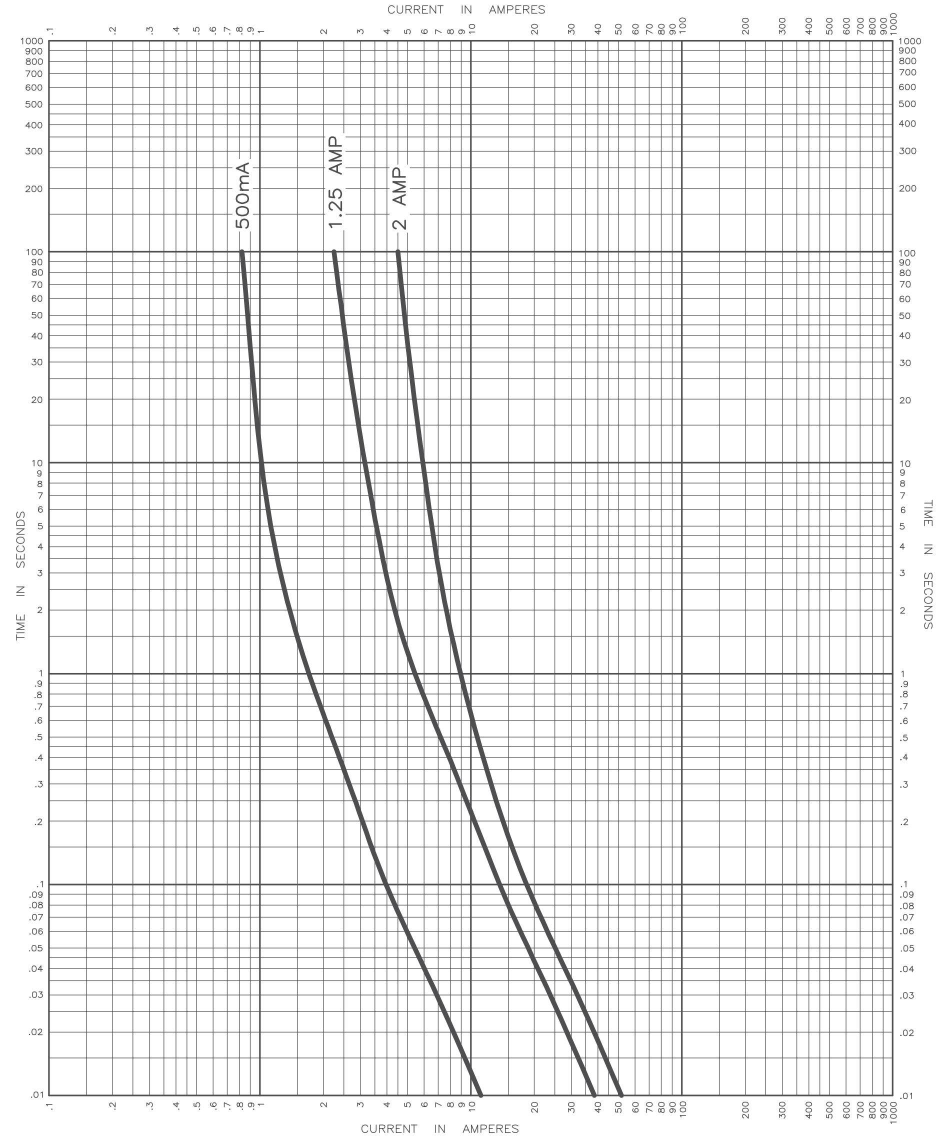
‡ Typical Voltage Drop (Measured at rated current after temperature stabilizes)

Figure 8 shows the time current curves of the TCP fuse series. This figure is used to verify use of the TCP1.25A with the SMP100MC-270. For the second level, the fuse has to blow before the TRISIL is damaged, so to verify this point we must compare the I_{TSM} points of the SMP100MC with the time current points of the TCP1.25A. Please note that the I_{TSM} points are given in peak values while the TCP curve is given in rms values.

Duration	.01s	.1s	1s	10s	100s
TCP1.25A	42A	14.5A	5.5A	3.2A	2.3A$_{(RMS)}$
SMP100MC	43.1A	17A	9A	4.5A	3A$_{(RMS)}$

The comparison of TCP1.25A and SMP100MC datasheet values shows that this solution is convenient for this application. The next section will refer to test performed on such a module.

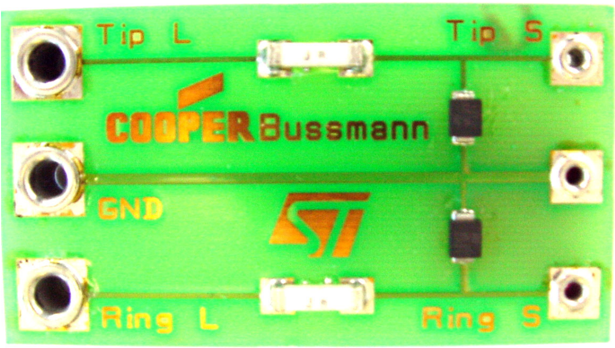
Figure 8: TCP1.25A time current curve



5. US market telecom protection tests

A PCB has been developed according to the criteria established earlier (see figure 9). These boards, equipped with two fuses TCP1.25A from Cooper Bussmann and two TRISILs SMP100MC-270, have been tested.

Figure 9: Picture of the developed board



The schematic of these tested boards is given in the figure 10 and performed tests were based on Telcordia (Bellcore) GR1089 for both lightning and power mains disturbances.

. Lightning surge 10/1000µs +/-1kV 100A (25 pulses in each polarity)
. Lightning surge 2/10µs +/-2.5kV and 5kV 500A (10 pulses in each polarity)
. Power mains disturbance 600V 3A 1.1s
. Power mains disturbance 277V 25A 15mn
. Power mains disturbance 600V 60A 5s

Figure 10: Test board diagram

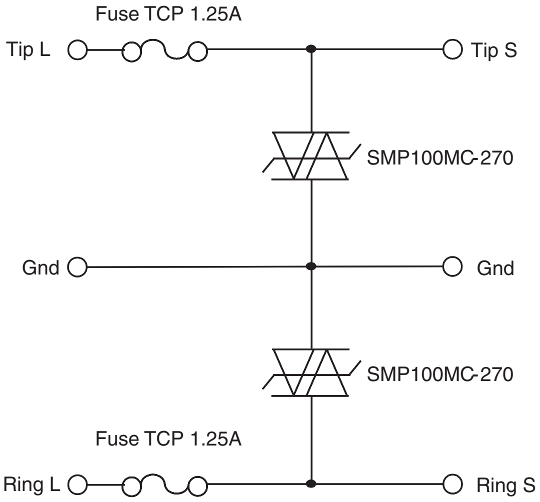
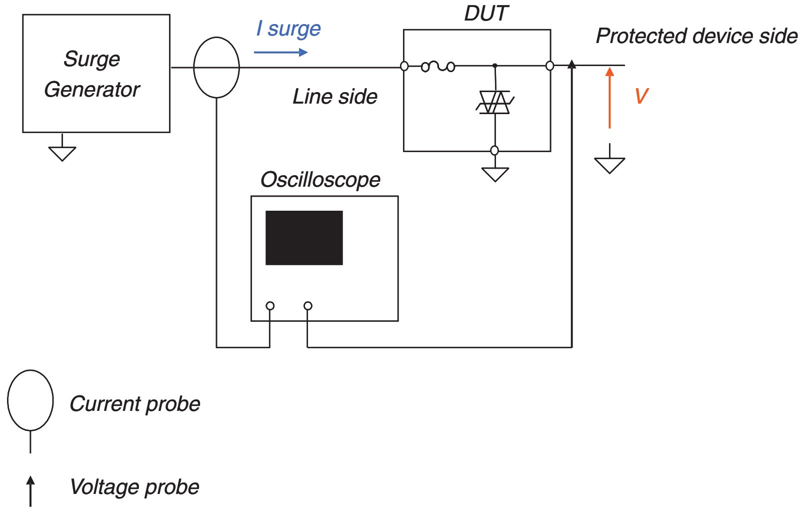


Figure 11 shows the measurement circuit used for this test series. During lightning and mains contact tests, the surge current (I surge) injected in Tip L or Ring L (transversal tests) or both Tip L and Ring L (longitudinal tests) has been measured. The remaining voltages at Tip S or Ring S have been also measured (V).

Figure 11: Measurement circuit



The curves of the figures 12, 13 and 14 show the results, respectively, of :

- a case of lightning test
- a case of first level AC power fault test
- a case of second level AC power fault test.

These curves show no impact of both fuses and TRISIL during first level tests while the fuses open safely during certain second level tests.

Figure 12: Module behavior during 2/10µs 500A surge test

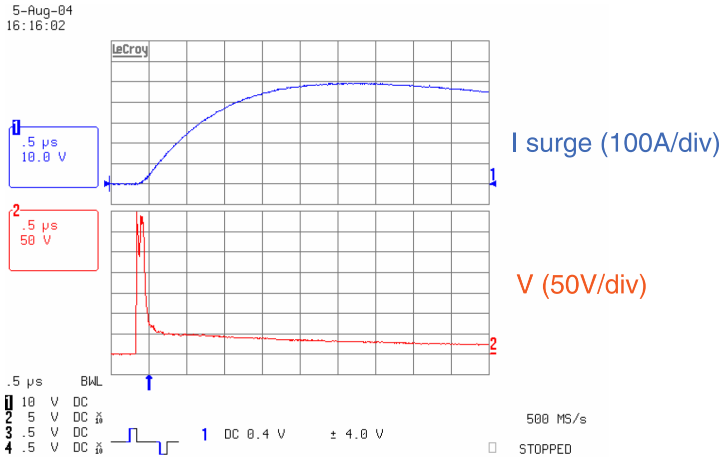


Figure 13: Module behavior during 600V 3A 1.1s surge test

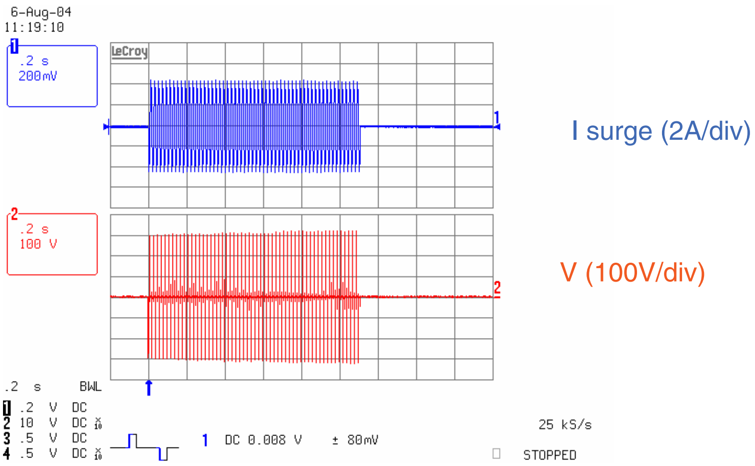
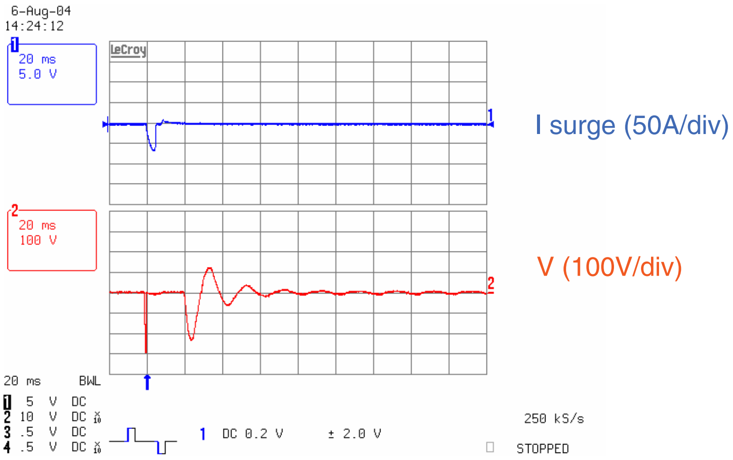


Figure 14: Module behavior during 600V 60A 5s surge test



Today and for several years to come, wireline networks remain an efficient and cost effective mean to exchange data around the world. The length of these copper lines require system designers to focus on line interface protection. These protection stages must be in accordance with the standards where equipment operates. This document has given the philosophy of such a protection and proposes practical results of tests.

The modules tested were dedicated to US market for CO equipments and were equipped with two TCP1.25A fuses from Cooper Bussmann and two SMP100MC-270 TRISIL from STMicroelectronics. Same results have been found with two SMP100LC-270 and two TCP1.25A. The results of these experiments proved the compliance of this solution with Telcordia (Bellcore) GR1089 standard. The same approach can be used to protect other kinds of modules (i,e terminal) or CO modules for other countries.

Table 6: Revision History

Date	Revision	Description of Changes
11-Jul-2005	1	First issue.

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