AND8022/D

TSPD (Thyristor Surge Protective Devices)

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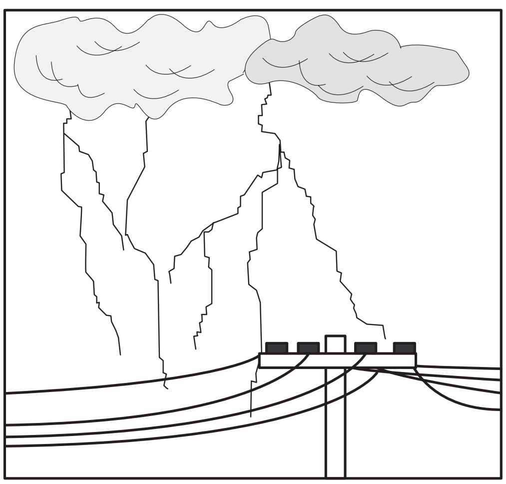
APPLICATION NOTE

INTRODUCTION

The current Telecom infrastructure in special the two wire systems are exposed to the outside environment and are susceptible to any electromagnetic disturbance caused by lightning strikes during a thunderstorm or by Power Induced due to High Voltage power lines. These situation generates in the Telecom wire system very fast Transients of Voltage of Several hundreds or Volts that can harm people if they are using an unprotected telephone handset during these situations, and destroying the telecom equipment connected to the telephone line.



Lightning causes a large shift in ground potential near a lightning strike. These shifts can reach as high as 50 KV. Large magnetic fields from lightning strikes may also cause problems.

In addition to the traditional gas–discharge tubes (GDT), metal oxide varistors (MOVs), and fuses, very effective semiconductor devices are appearing that protect on–board electronics against real–world insults. Protecting your products against lightning, electrostatic discharge (ESD), electrical fast transient (EFT), inductive load switching, and AC line fluctuations has the obvious advantage of making them more rugged, thereby lowering your warranty costs.

A gas discharge tube (GDT) is simply two electrodes that are held at a close distance within a gas filled tube. When high voltages (150 V, 230 V, 260 V and 350 V) are applied to the electrodes, the gas inside ionizes and current begins to flow. In the off–state, the resistance across the tube is very high; when conducting, the resistance is low. GDTs are relatively slow, but can handle very large levels of surge. Unfortunately, some gas tubes' electrodes burn out after a few hundred hits.

A MOV is an inexpensive, rugged device capable of absorbing very large currents without damage. Every time they conduct, however, their capacity degrades and they are known to fail open circuit when over stressed. Semiconductor–based suppressors, on the other hand, do not have a wear–out mechanism, if properly specified. The MOV, a compressed–powder products is commonly thought to have slower reaction time than semiconductor protection devices, but this is not necessarily true.

Transient voltage suppressor (TVS) are diodes specifically designed to provide overvoltage protection. TVS diodes are characterized by their high surge capability, low operating and clamping voltages and virtually instantaneous response time. These characteristics make them ideal for use as board level protection.

Ideally, the capacitance of a shunt protection device should be zero. Typical numbers of gas–discharge tubes are from 1 to 1.25 pf. Semiconductor devices range from 100 to 5000 pf.

Now, one of the most reliable semiconductor device used in the actual telecom infrastructure for protection purposes against overvoltage conditions is the TSPD. TSPD is the abbreviation of “Thyristor Surge Protective Device” and it is a two terminal solid state device capable to drain a surge current pulse to ground when a transient voltage appears in between its two terminals when a specific maximum voltage delimited by the maximum breakover voltage of the device is reached.

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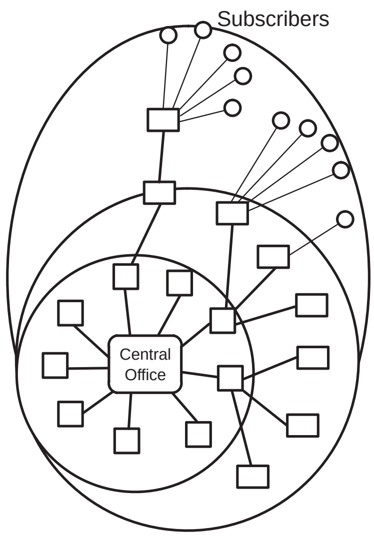
The TSPD complies with two main objectives:

- Protect the people against hazardous electrical environments due to lightning and accidental or induced power line crossing while they are using the telephone line.
- Protect sensitive telecom equipment as telephone sets, switchboards, modems, etc.

The TSPD devices must be selected depending in the level of protection required since there are different definitions for each level of protection.

WHAT LEVEL OF PROTECTION IS REQUIRED?



To take as a reference, it depends of the telephone lines density. Central offices usually are located in the urban zones and has the highest line density and the level of protection is different compared to residential zones or rural zones, where the line density is lower.

When a voltage transient with an associated surge current comes at urban zones it is distributed and absorbed by a large number of lines, but this situation at just few lines at rural zones is more dangerous for the people and the equipment.

According to the industrial standard BELLCORE GR–1089–CORE, the levels of protection to be covered by the TSPDs are classified in three main categories:

- Primary Protection (Central Offices, Switchboards)
- Secondary Protection (Modems, Internet Hardware, COAX, HFC)
- Station Protection (Modems, Home Telephone Set, Voicemail)

This industrial standard also establish that each of the previous categories have different lightning surge ratings depending in the telephone lines density and the kind of applications, these surge ratings are described in the following tables:

Primary Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μs)	Current Waveform (μs)	Rating IPP (A)
BELLCORE GR–1089–CORE First Level	2500 1000	2x10 10x1000	2x10 10x1000	500 100
BELLCORE GR–1089–CORE Second Level	5000	2x10	2x10	500

Secondary Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μs)	Current Waveform (μs)	Rating IPP (A)
BELLCORE GR–1089–CORE First Level	2500 1000	2x10 10x1000	2x10 10x1000	150 50
BELLCORE GR–1089–CORE Second Level	5000	2x10	2x10	150

Station Protection

Standard Number	Peak Surge Voltage (V)	Voltage Waveform (μs)	Current Waveform (μs)	Rating IPP (A)
BELLCORE GR–1089–CORE	1000	10x1000	10x1000	300
BELLCORE GR–1089–CORE	2000	1.2x50	8x20	1000

In addition to the previous surge ratings, BELLCORE industrial standard also establish two main categories of operating temperature range to be covered by the TSPDs:

- **Controlled temperature environment** represents a temperature range having the extreme values of 2°C and 50°C.
- **Uncontrolled temperature environment** represents a temperature range having the extreme values of –20°C and 65°C.

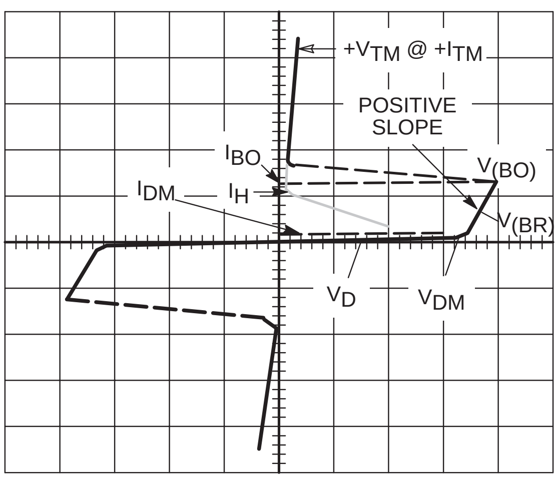
Based in all the previous information, it is clear that the telecommunications systems are particularly vulnerable to lightning–induced surges. Consequently, telephone–company standards have long mandated the use of two levels of protection: a primary suppressor on each line to absorb the major part of the overvoltage transient, and secondary protection devices mounted on individual printed–circuit boards to eliminate the residual overvoltage spikes. The primary suppressors must have higher surge capabilities and be able to withstand very high voltages. So, traditional solutions are based on gas discharge–tube or carbon spark–gap technology, but these elements have some disadvantages when compared with the TSPDs.

ON Semiconductor has already introduced two series of TSPDs DEVICES for lightning surge protection of the two wire telecommunications systems, these TSPD devices were developed in SMT package (SMB case 403C), and the reason why there are two series is to cover the applications for Central office primary protection and secondary protection respectively:

- MMT05B230,260,310T3 series intended for secondary protection
- MMT10B230,260,310T3 series intended for central office primary protection

As previously explained, the TSPD is the abbreviation of "Thyristor Surge Protective Device" and it is a two terminal solid state device capable to drain a surge current pulse to ground when a transient voltage appears in between its two terminals when a specific maximum voltage delimited by the maximum breakover voltage of the device is reached. These Thyristor Surge Protection Devices are bi–directional and prevent overvoltage damage to sensitive circuits by lightening induction, and power line crossing. They are breakover triggered crowbar protectors with turn off occurring when the surge current falls below the holding current value.

The following plot shows what the Electrical Characteristics of a TSPD are:



- VDM is the maximum value of voltage may be applied to the TSPD in which it will remain its off–state
- V(BR) is the voltage value in which the TSPD reaches its Zener Region
- V(BO) is the breakover voltage in which the TSPD triggers itself whenever its I(BO) value at this point of voltage is reached
- IDM is the leakage current corresponding to the VDM value
- I(BO) is the minimum current needed to trigger the TSPD once it has reached its V(BO) value
- IH is the minimum current needed to keep the TSPD in the on–state once it has been triggered
- VTM is the voltage drop in the TSPD when a certain value of current is flowing through itself

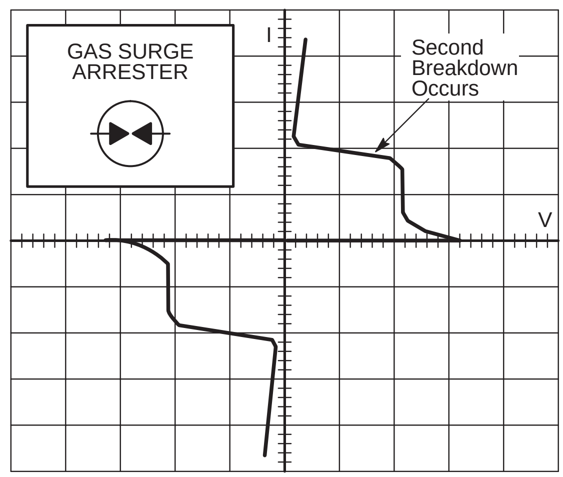
Through the previous plot, it is possible to observe that the TSPD will be triggered whenever its V(BO) value is reached and it will be able to drain to ground the surge current pulse may be caused due to lightning conditions.

BUT HOW A TSPD IS COMPARED WITH GDTs AND MOV DEVICES:

Gas Discharge Tubes (GDTs)

As previously described, the GDT has a sealed construction with two terminals and inside two electrodes with small gap between. In this small volume, it is trapped a gas with a specific ionization level, therefore, when a voltage transient occurs the ionized gas serves as a current path.

The following plot shows the typical operation behavior of a GDT (V–I characteristics):

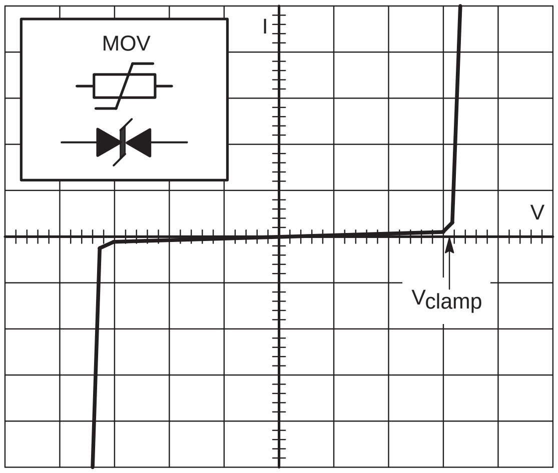


In this plot, it is possible to observe that the GDT's response is relatively slow, and sometimes this factor could be very critical for telecom applications in which the fast response is needed. In addition, as a result of this slow response, some gas tubes' electrodes burn out after a few hundred hits.

MOV's

These solid state devices are in essence two Zener Diodes with the cathodes tied together and the voltage limitation is dependent of the Zener voltage of each Zener diode. In these devices the power dissipation is very high.

The following plot shows the typical operation behavior of a MOV (V–I characteristics):



When a MOV reaches its Zener voltage, it starts to dissipate power, so this is why, if a high transient voltage occurs, the MOV may be damaged because of the high power dissipation that this transient may cause. At the same time, it is very common that the MOV becomes degraded each time it is activated.

WHAT THE MAIN ADVANTAGES AND DISADVANTAGES OF THE TSPD ARE:

Advantages:

- There is no wear–out (Aging) mechanism present on the Gas Discharge Tubes
- Very fast turn–on switching
- Electrical Parameter very consistent (VBO, V(BR), IH)
- High immunity to dV/dt conditions (> 2 KV/μsec)
- Compared with the MOVs, the total energy dissipated is lower due to the crowbar characteristics that these MOVs devices do not have
- Similar current surge capabilities of the GDTs
- Short circuit mechanism for extra protection of the equipment
- Meet the specifications of the industrial standard BELLCORE GR–1089–CORE

Disadvantages:

- Limitation for very high current surge pulses. For this, more silicon is needed
- Temperature dependency of the electrical parameters
- Surge performance limited at low temperatures (–20°C)
- Capacitance is dependent of the die size

WHAT THE MOST IMPORTANT PARAMETERS OF A TSPD ARE:

Static and Dynamic Parameters:

DC Characteristics:

- Breakdown Voltage
- Breakover Voltage
- Off–State Current
- Breakover Current
- On–State Voltage
- Holding Current

AC Characteristics:

- Surge Capability at specific double exponential waveform (i.e. 10x1000 μs, 2x10 μs, 8x20 μs, etc)
- dV/dt immunity
- Capacitance at Zero dc bias and 50 Vdc at 1 MHz

TSPD CONFIGURATIONS FOR TELECOM APPLICATIONS CIRCUITS

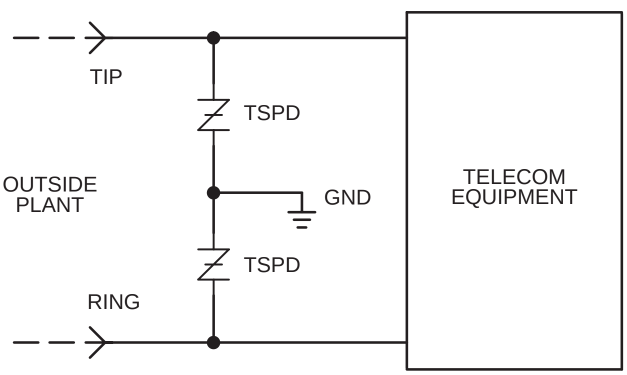
Based in the industrial standard BELLCORE GR–974–CORE, this generic requirements document contains Bellcore’s view of proposed requirements for Telecommunications Line Protector Units (TLPUs). These generic requirements should be met to satisfy the needs of the telecommunications network applications of a typical Bellcore Client Company (BCC). TLPUs installed in their protector mountings are intended to prevent unwanted surge voltages and currents on the outside plant from reaching terminal equipment used in telecommunications networks. These unwanted surges may arise, for example, from effects of lightning or power line faults.

The TLPU is intended to be used at central offices and customer stations, and on carrier systems. The TLPU has the capability of providing voltage–only or combined voltage and current–limiting features. Therefore, the TLPUs consist of voltage–limiting devices **(TSPD)** from tip to ground and ring to ground, and they may also contain a current–limiting device (PPTC, Heat Coil) on each conductor (tip & ring) between the voltage–limiting device and the protected load.

This industrial standard proposes generic requirements that a TLPU shall have in order to avoid interference with the operation of telecommunications networks and also to provide surge limiting that is compatible with the telecommunications networks. Through this document, with few exceptions, the proposed requirements are derived independently of the capabilities of anticipated TLPU technologies. The requirements are based on the needs of the telecommunications networks.

CONFIGURATION 1.

In this configuration, the Telecommunications Line Protector Unit (TLPU) only consist of voltage–limiting devices **(TSPDs)** which must be connected from Tip to Ground and Ring to Ground. The following figure shows the application schematic for this configuration:



This plot shows the typical schematic diagram for a telecom system of two wires (Tip and Ring), here, the TSPD devices will be acting as an open circuits whenever the signal voltage in the Tip and Ring lines is lower than their VBO. Typically the voltage in the Tip and Ring lines is in between 50 V and 140 V depending in the kind of application. If a transient voltage occurs in any of the two telecom lines (Tip or Ring), the corresponding TSPD device will be triggered draining the surge current (10x1000 µsec, 2x10 µsec, 8x20 µsec) to ground and protecting the Telecom Equipment, then, as soon as the surge current drops below than the IH value of the TSPD, it will get its off–state and will be ready to act again if another transient voltage occurs. The TSPD will be operating anytime that their VBO is reached and will not get damaged if their maximum surge current rating is not exceeded.

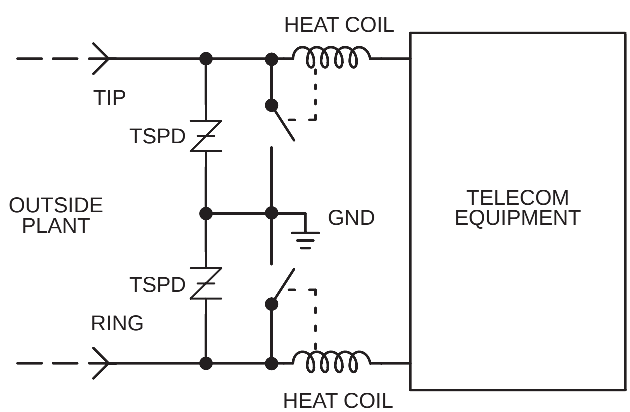
The main disadvantage of this configuration is that there are not any current–limiting devices (PPTC, Heat Coil) that can protect the lines against overcurrent conditions, so it could be critical for the TLPU since if there is an overcurrent condition in any of the two lines (Tip and Ring), it could be possible to have failures in the Telecom Equipment caused by these overcurrent conditions.

CONFIGURATION 2.

In this configuration, the Telecommunications Line Protector Unit (TLPU) consist of voltage–limiting devices **(TSPDs)** and current–limiting devices (PPTC, Heat Coil) in each conductor (tip and ring) between the voltage–limiting device and the protected load. The voltage–limiting devices must be connected from Tip to Ground and Ring to Ground and the current–limiting devices must be connected in series with each of the telecom lines. There are two different current–limiting devices commonly used for these purposes: one of them is named "Heat coil" and the other one is named "PPTC". The following figures show the application schematics for each option:

Option 1:

Voltage–limiting devices – TSPDs (Thyristor Surge Protective Devices)
Current–limiting devices – Heat coil



In the same way than in the configuration 1, the TSPD devices will be acting as an open circuits whenever the signal voltage in the Tip and Ring lines is lower than their VBO. If a transient voltage occurs in any of the two telecom lines (Tip or Ring), the corresponding TSPD device will be triggered draining the surge current (10x1000 µsec, 2x10 µsec, 8x20 µsec) to ground and protecting the Telecom Equipment, then, as soon as the surge current drops below than the IH value of the TSPD, it will get its off–state and will be ready to act again if another transient voltage occurs. The TSPD will be operating anytime that their VBO is reached and will not get damaged if their maximum surge current rating is not exceeded.

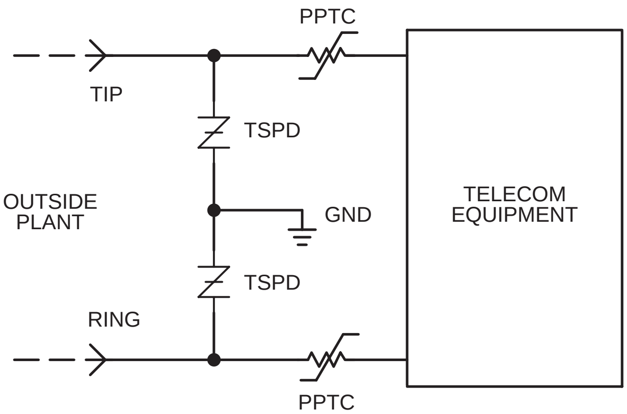
The main advantage of this configuration is that it has one heat coil (current–limiting device) in each of the telecom lines which provide protection to the Telecom Equipment against overcurrent conditions. In the case that an overcurrent condition occurs, the coil will be heated and because of this the normal–open switch will be closed allowing current flow to ground through itself, and with this, the Telecom Equipment is protected.

The disadvantage of these current–limiting devices (Heat Coil) is that once they have been activated, they must be changed since it is not possible to de–activate their contacts, so the contact would remain closed until the device is changed.

Option 2:

Voltage–limiting devices – TSPDs (Thyristor Surge Protective Devices)

Current–limiting devices – PPTC (Polyswitch Polymeric Positive Temperature Coefficient devices).



Similar than in the configuration 1 and configuration 2 (option 1), the TSPD devices will be acting as an open circuits whenever the signal voltage in the Tip and Ring lines is lower than their VBO. If a transient voltage occurs in any of the two telecom lines (Tip or Ring), the corresponding TSPD device will be triggered draining the surge current (10x1000 μsec, 2x10 μsec, 8x20 μsec) to ground and protecting the Telecom Equipment, then, as soon as the surge current drops below than the IH value of the TSPD, it will get its off–state and will be ready to act again if another transient voltage occurs. The TSPD will be operating anytime that their VBO is reached and will not get damaged if their maximum surge current rating is not exceeded.

The main advantage of this configuration is that it is contemplating one PPTC (current–limiting device) in each of the telecom lines which provide protection to the Telecom Equipment against overcurrent conditions. Differently than the heat coil option, the PPTCs are commonly called “resettable fuses” to distinguish them from the traditional fuses that work only once and then must be replaced–an expensive and inconvenient proposition. Like traditional fuses, PPTCs interrupt the flow of dangerously high current during fault conditions. But unlike traditional fuses, PPTCs automatically reset after the fault is cleared and power to the circuit is removed, thereby reducing warranty, service, and repair costs. Because they are solid state devices, PPTCs are also better able to withstand mechanical shock and vibration, and provide reliable protection in a wide variety of applications. The PPTC device protects the circuit by going from a low–resistance to a high–resistance state in response to an over current. This is called “tripping” the device. Generally, the device has a resistance that is much less than the remainder of the circuit, and has a little or no influence on the normal performance of the circuit. But in response to an overcurrent condition, the device increases in resistance (trips), reducing the current in the circuit to a value that can be safely carried by any of the telecom equipment. This change is the result of a rapid increase in the temperature of the device, caused by the generation of heat within the device by I2R heating.

In summary, through this application note, it has been shown the main advantages that the TSPDs devices can offer to protect the two wires telecom equipment against overvoltage conditions caused by effects of lightning or power line faults. In addition, it is important to mention that the TSPDs devices manufactured by ON Semiconductor meet the specifications established in the industrial standard BELLCORE GR–1089–CORE and GR–974–CORE which guarantees the efficient and the good operation of them within the field of the telecom applications.

Notes

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