

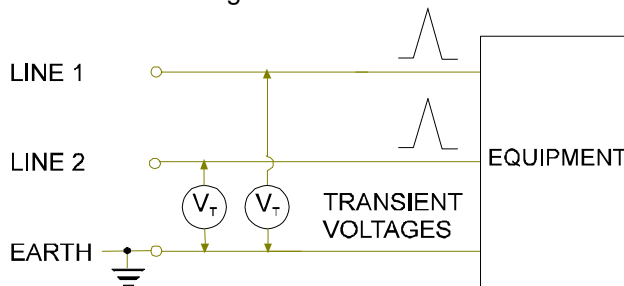
Telecommunication Line Protectors

1.1 The nature of telecom surges

The telecom services considered in this report are transported on twisted pair. Each service has two wires, or lines, sometimes called the 'a' and 'b' wires.

Surges can thus occur from each line to ground, known as L-G or common mode, or occur across the lines, known as L-L or differential mode.

The surges that occur from each line to ground, usually do so of the same magnitude at the same time, hence the name common mode. This is an important observation and derives from the fact that these twisted pairs are balanced, and hence noise signals or surge energy is coupled onto both wires equally. The receiving telecommunications equipment is looking for differential signals, and is most sensitive to noise and surges in the differential mode. That is, the telecom equipment is generally more robust against common mode L-G signals. The following diagram illustrates the idea of a common mode surge.



We will see later that gas arrester only protection is usually sufficient for L-G protection.

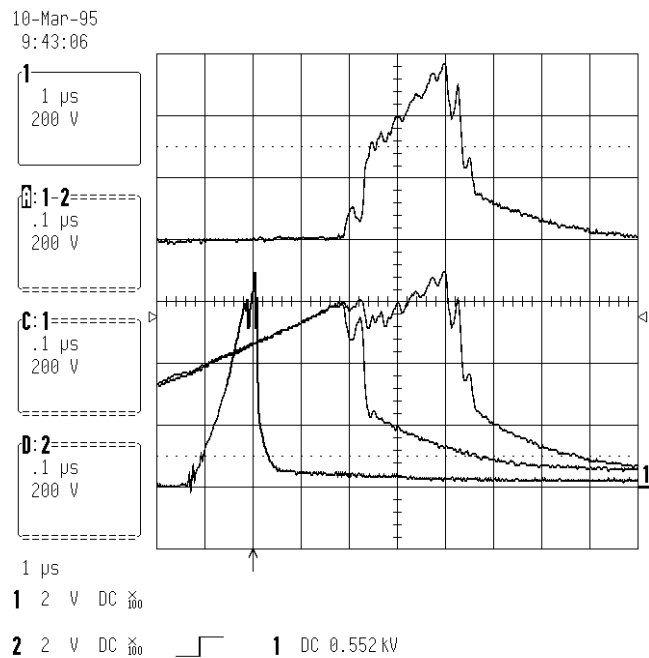
Surges on balanced pairs usually start out as common mode.

Telecom equipment is relatively robust to these signals.

That part is the good news. Problems can arise, however, that convert these common mode signals to differential mode. If one wire in the pair actually breaks down to ground either through insulation failure or insufficient clearance at a connection point, that wire drops to ground potential, while the other pair remains at high voltage potential. Thus, a large voltage then appears across the line, converting what was a common mode (L-G on each line) surge into a damaging differential mode (L-L) surge.

In a similar manner, surge protection components applied from each line to ground must operate at the same time and behave in the same way. If the surge protection component on the 'a' wire operated before the surge protection component on the 'b' wire, then the common mode signal would be converted to a differential signal for the time period between both surge protection components operating. This phenomena is worse when independent components are used, such as two independent gas arresters. To try to minimize this problem, most protectors use a three terminal gas arrester. However, the problem is not completely eliminated as many suppose. The following oscilloscope display indicates this.

In this test, an equal impulse is applied from L-G on both leads of a three terminal gas arrester. The lower, left hand side trace shows this impulse on a scale of 1us per division, where the absolute peak of this impulse is around 700V (all traces are 200V per division). The lower, central, two traces show the voltage on each of the leads of the gas arrester. Both are climbing equally, until at around 600V one half of the gas arrester fires, rapidly reducing the voltage on that lead. However, the other continues to climb until around 700V until it fires. The top central waveform shows the difference between these waveforms – it is a pulse of around 600V, resulting in the damaging L-L, or differential mode!

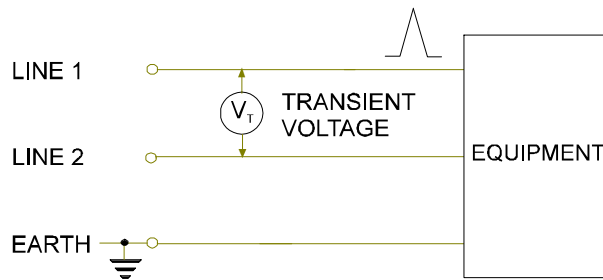


So, to summarize this, the following points need to be understood:

Differential, or L-L, surges are most damaging.

L-G surges can get converted to damaging L-L surges.

The following diagram illustrates a L-L surge.



1.2 Test impulses used to represent typical telecom surges

In order to develop and test products, various standard waveshapes are commonly used. For telecom protectors there are two main generators used as follows:

Generator (Standard)	Voltage Waveform	Current Waveform	Generator output impedance
ITU K.20	5kV, 10/700us	125A, 5/310us	40 Ohms
IEEE C62.45	6kV, 1.2/50us	3kA, 8/20us	2 Ohms
	20kV, 1.2/50us	10kA, 8/20us	2 Ohms

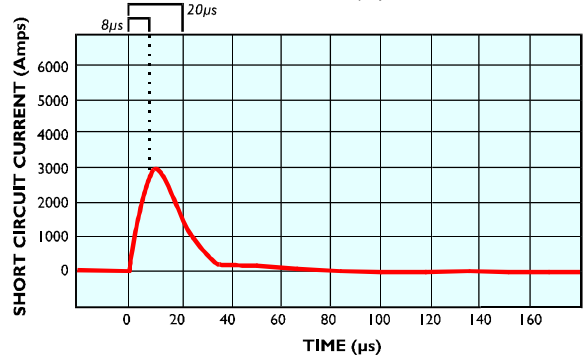
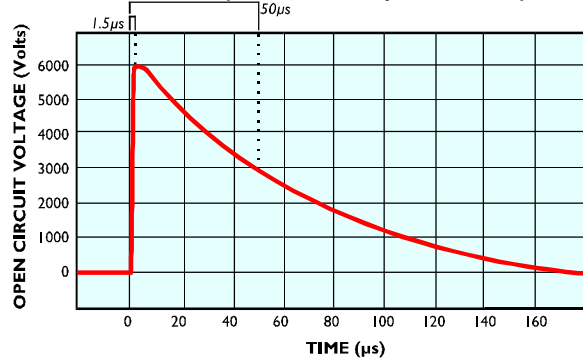
The first is the ITU (formerly CCITT) type waveform – known as the 5kV, 125A, 10/700us waveform. This waveform is a relatively low energy one, and is taken to represent the type of impulse a protector might be expected to cope with if it were connected to a pair from an underground, multi-pair cable (where a nearby lightning strike would couple into, and share amongst, perhaps 200 pairs).

In specifying waveforms and generators, it is important to understand that the generator only has one output, and that the voltage waveform is actually the open circuit voltage that the generator puts out, and the current waveform is the current that flows into a short circuit on the generator terminals. From a surge protection point of view, the voltage output causes the protector to conduct, and allows us to measure the maximum voltage that the protector clamps to. Once clamping occurs, current

begins to flow in the surge protector, and we can measure how much surge current the protector can cope with.

In practice, either waveform lets us measure the “let-through” or clamping voltage of a protector, and the 8/20us current waveform lets us measure how rugged the protector is.

The following two waveforms are for the IEEE type waveform. In specifying the voltage waveform, the 1.2us is roughly the rise time of the impulse, and the 50us is the time taken for the pulse to decay to half its peak value. Similarly, for the current waveform, the 8us is roughly the rise time of the impulse, and the 20us is the time taken for the pulse to decay to half its peak value.



Similar graphs could be drawn for the ITU type waveform.

Test waveforms let us test and compare protectors.

We can measure the “let-through” or clamping voltage.

The current waveform lets us measure how rugged a protector is.

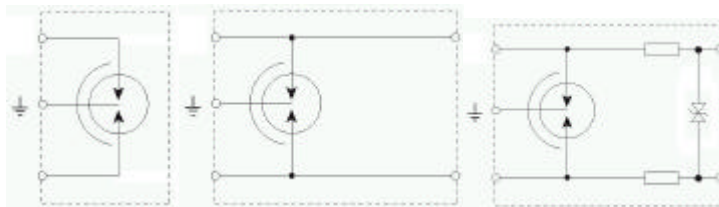
2 Telecommunications Surge Protector Topologies

Telecom protectors can be configured in various ways. Terms often used, mis-used, and mis-understood, are Points and Stages.

Referring to a protector as a so-many point protector is explained as follows:

Type	Description
2-Point Protector	The protector only has 2 connections – these would connect to each wire of the pair. It is a parallel protector, not inserted in series with the pair to be protected.
3-Point Protector	The protector has 3 connections – these would connect to each wire of the pair, and one to ground. It is a parallel protector, not inserted in series with the pair to be protected.
5-Point Protector	The protector has 5 connections – there are two connections to the input of the protector, two separate connections being to the output of the protector, and one to ground. It is a series protector, inserted in series with the pair to be protected.

For example, consider the circuit diagrams below. The one on the left is a 3-point protector, and other two are 5 point protectors.



3, 5 & 5 Point Protectors

Note that this 'point' term really does not say much about the internal construction of the protector. The center protector consists of a single gas arrester, but the one on the right consists of a gas arrester, two series impedances, and a secondary clamp element. Some people think that a 5-stage protector contains 5 internal elements. Now that we've looked at these examples, we know better.

Which brings us to Stages. There is no universal agreement on exactly what constitutes an n-stage protector. The idea is that the more stages, the more

complex the schematic of the protector. Using the above examples, the left two protectors would be considered single stage protectors, since they contain only a single primary clamping element. The one on the right would be considered either a 2-stage protector (because it has a primary and secondary clamping element), or would be considered a 3-stage protector (because it has a primary clamping element, series current-limiting impedances, and a secondary clamping element). A schematic diagram is really the only way of determining the construction of a surge protector.

Confusion exists with the meaning of Points and Stages.

Use the SCHEMATIC DIAGRAM to determine what's in a protector.

3 Primary Overvoltage Protection

All telecom surge protectors contain primary overvoltage protection. It is the stage of protection providing the voltage limiting function, and generally diverts the surge current to ground. Although this element could be a gas arrester, MOV, or silicon diode, it is virtually universally recognized that Asian conditions require the primary protector to be a gas arrester.

Although some designs use two separate 2-terminal gas arresters, it has been shown in section 1.1 that this can cause problems, and virtually all designs now use a 3-terminal gas arrester.

The selection criteria for a gas arrester is its let-through voltage (turn-on time), and its current handling capability.

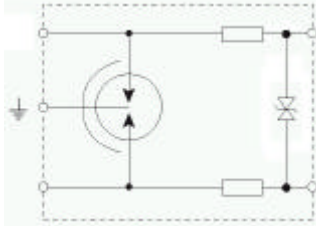
When tested to standard waveforms the let-through performance can vary from around 350V to 800V depending on arrester manufacturer and construction technique.

The surge handling capability is usually determined by the primary overvoltage protector, but may actually be limited by wiring that fuses or other weaker link. The normal values for 3-terminal gas arresters are 5kA or 10kA 8/20us from each line to ground.

One final point. Some gas arresters are fitted with a fail-safe shorting clip. In the event that high AC currents find themselves on the pair and the arresters fires and does not go out, it is possible for it to heat to the point where it could cause a fire. The function of the fail-safe shorting clip is to react in this situation and irreversibly short out the gas arrester. This activation usually occurs by melting solder or plastic piece. This scenario is usually caused by direct contact of the pair with AC voltages, and generally not by induction.

4 Secondary Overvoltage Protection

A premium telecom surge protector will have a secondary overvoltage clamping element. This is usually configured from line to line and is either a MOV or a silicon diode. A schematic for such a device is shown:



The secondary element is generally a purpose-designed telecom protection thyristor component. These components have developed to the point where they are robust, have excellent, instant, clamping performance, and feature low capacitance, and have rendered MOV's or Transzorb diodes obsolete in this application.

The secondary L-L clamp is very important since it provides protection for the damaging L-L voltages as explained in section 1.1.

The series elements are needed to coordinate the operation of the primary and secondary clamping elements. When a surge comes along, the thyristor instantly clamps, and current begins to flow through the secondary protector. In the absence of the series elements, the thyristor would clamp and prevent the gas arrester from firing, thus forcing the thyristor to take the entire surge energy. However, the current flowing through the thyristor flows through the series element (when present) causing an additional voltage drop, that added to the thyristor voltage, causes the gas arrester to fire and take the brunt of the surge energy, while the thyristor provided low let-through voltage.

The series elements need to be rugged, and experience has shown that carefully selected wire wound resistors offer the best combination of low inductance and high surge current withstand.

Primary gas arresters provide high energy ability.

Secondary telecom thyristors provide low let-through voltage.

5 Overcurrent Protection

Where AC power circuits and telecom services are run in close proximity for large distances, usually external to the building, another problem can occur. That is, a line to ground fault on the AC circuit can cause thousands of

amps of fault current to flow in the AC wiring. This in turn, can couple into the too-close telecom wiring, causing several amps of AC current to flow in the telecom wiring. This current can cause failure of the telecom line cards or other terminating equipment.

In many countries, there are agreements between the power utilities and the telecom providers that ensure adequate separation of these services, so this problem is not a very common occurrence.

The normal way to protect against this problem, is to have PTC's in series with each line of the telecom surge protector. These act like solid-state resettable fuses, and are normally arranged to operate at around 200mA, a value chosen to be above the normal telecommunication line current, yet below the value at which damage occurs.

Like many good ideas, there is a down-side to providing PTC's in the circuit. They need to be carefully matched in resistance value to avoid unbalancing the line. Not only does their initial un-tripped resistance need to be matched (which is difficult with this type of component), but these PTC's typically do not return to their initial pre-tripped resistance after resetting. Thus, their degree of unbalance gets worse with subsequent tripping. Unbalance causes crosstalk into adjacent circuits, with the problem getting worse with higher frequency services. Impedance Balance and Return Loss are other measures used to assess the degree of unbalance, and the suitability for high frequency use.

Given that this type of overcurrent protection is often not required, it is not usually provided in order to avoid problems with Impedance Balance and resultant crosstalk.

Overcurrent protection is often not required due to the cooperative agreement between power and telecom utilities.

Provision of overcurrent protection can cause crosstalk problems.

6 Frequency Response

A plain ordinary telephone service (POTs) provided on 600 Ohm twisted copper pair requires a bandwidth of 300Hz to 3400Hz. At these low frequencies, provision of Telecom Surge Protection rarely provides attenuation problems.

However, with the trend to ever higher frequencies required to support digital services, the issue of the

attenuation caused by the surge protection can no longer be ignored.

Surge protectors can inadvertently attenuate the telecom signal by virtue of series impedance and shunt capacitance.

Series impedance need to be of low resistance and especially of low inductance. The resistance component produces a fixed attenuation independent of frequency, but any inductance present causes increasing attenuation with frequency. Similarly, shunt capacitance causes attenuation that gets worse with increasing frequency.

The series impedance problem is generally solved by choosing low inductance resistors. The ideal resistance value from a surge protector point of view is around 8 to 10 ohms, but can be dropped to less than half that with a suitably rugged secondary protection element. For extremely low attenuation, a gas arrester only protector is used.

As discussed, thyristor elements are typically used for secondary clamping elements as their capacitance is lower than MOVs by an order of magnitude or more. However, if even more reduction in capacitance is required, an ingenious arrangement of putting the thyristor within a diode bridge is used. The diodes are chosen to be able to withstand the same surge energy as the thyristor, but they are inherently very low capacitance devices. The resultant capacitance of a larger capacitance in series with a smaller one is lower than either one. So, the bridge arrangement gives a very low overall capacitance at the expense of a few volts added to the let-through voltage (and the cost of the diodes themselves).

Need to consider attenuation of protector on telecom signals. Secondary protection CAN be provided with low attenuation.

7 Comparison of some Telecom Surge Protectors

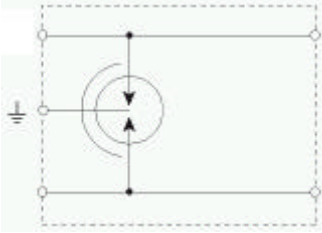

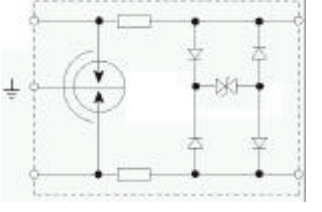

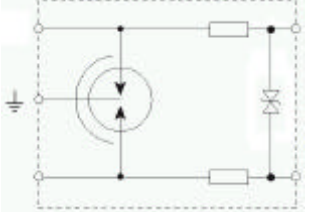

7.1 Protectors Compared

For the purposes of comparing and contrasting the previous points, three surge protectors available from ERICO for the Asian market for the KRONE-LSA disconnect distribution block have been chosen:

- a) CRITEC SLP10-K1F
- b) CRITEC HSP10-K230
- c) CRITEC SLP1-K2

Note:
KRONE and Krone-LSA are registered trademarks of KRONE GmbH, Germany.
CRITEC is a registered trademark of ERICO, Inc., USA.

7.2 Physical and Descriptive Comparison

Protector	Description	Schematic	Photos
CRITEC SLP10-K1F	A 230V gas arrester only, 10 pair protector.		
CRITEC HSP10-K230	A 230V primary gas arrester with decoupled low capacitance secondary thyristor, 10 pair protector.		
CRITEC SLP1-K2	A 230V primary gas arrester with decoupled secondary thyristor, single pair protector.		

7.3 Performance Comparison

Protector	Pairs protected	Primary GDT	Secondary Clamp	Let-through Voltage	Analogue Bandwidth	Digital Performance
CRITEC SLP10-K1F	10	Yes - 10kA	No	350 V typ.	12 MHz	8 Mbits
CRITEC HSP10-K230	10	Yes - 10kA	Yes	270 V typ.	12 MHz	8 Mbits
CRITEC SLP1-K2	1	Yes - 10kA	Yes	250 V typ.	3 MHz	2 Mbits

Notes:

- The 10 pair protectors offer much lower per-pair cost than the single pair protectors.
- Let-through figures are for the slower rise time ITU 5kV, 125A, 10/700us impulse. Faster impulses such as the IEEE 6kV 1.2/50us, 3kA 8/20us impulse have the effect of increasing the performance gap between those protectors with secondary protection and those without.

8 Conclusions

In determining the type of protector to employ, it needs to be understood how the various circuit topologies affect both the level of protection provided, and the underlying telecommunications signal. Given this, the three protectors above are rated as follows:

CRITEC SLP10-K1F	Good protector, giving reasonable protection, and allowing high frequency use.
CRITEC SLP1-K2	Better protector, giving excellent protection, and allowing reasonably high frequency use.
CRITEC HSP10-K230	Best protector, giving excellent protection, and allowing high frequency use.