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SERIES K: PROTECTION AGAINST INTERFERENCE

Surge protective component application guide – Gas discharge tubes

Recommendation ITU-T K.99

ITU-T

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Surge protective component application guide – Gas discharge tubes

Summary

Recommendation ITU-T K.99 describes the construction, characteristics, ratings and application examples of gas discharge tubes (GDTs) intended for the protection of exchange and outdoor equipment, subscriber or customer equipment and telecommunication lines from surges.

Version 2.0 of this Recommendation has added four informative appendices:

1) Appendix I: Durability test using "Fast" GDTs;
2) Appendix II: Spark-over dark effect;
3) Appendix III: GDT component form factors;
4) Appendix IV: Three-electrode GDT operation in Ethernet circuits.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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1 Scope

This Recommendation in the surge protective component application guide series covers gas discharge tube (GDT) technology. Gas discharge tubes are switching type overvoltage protectors [b-ITU-T K.96]. Guidance is given for [ITU-T K.12] compliant GDTs covering; construction, characteristics, ratings and application examples.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.12] Recommendation ITU-T K.12 (2010), *Characteristics of gas discharge tubes for the protection of telecommunications installations*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 arc mode [ITU-T K.12]: The lowest impedance or on-state of a gas discharge tube during normal operation.

3.1.2 arc voltage [ITU-T K.12]: The voltage measured across the tube while in lowest impedance state or arc mode.

3.1.3 breakdown [ITU-T K.12]: See "spark-over".

3.1.4 d.c. holdover voltage [ITU-T K.12]: The maximum d.c. voltage across the terminals of a gas discharge tube under which it may be expected to clear and to return to the high impedance state after the passage of a surge, under specified circuit conditions.

3.1.5 discharge current [ITU-T K.12]: The current that passes through a gas discharge tube when spark-over occurs.

- **discharge current, alternating**: The r.m.s. value of an approximately sinusoidal alternating current passing through the gas discharge tube.
- **discharge current, impulse**: The peak value of the impulse current passing through the gas discharge tube.

3.1.6 discharge voltage [ITU-T K.12]: The voltage that appears across the terminals of a gas discharge tube during the passage of discharge current.

3.1.7 gas discharge tube [ITU-T K.12]: A gap, or several gaps, in an enclosed discharge medium, other than air at atmospheric pressure, designed to protect apparatus or personnel, or both, from high transient voltages.

3.1.8 glow current [ITU-T K.12]: The current which flows after spark-over when circuit impedance limits the discharge current to a value less than the glow-to-arc transition current.

3.1.9 glow mode [ITU-T K.12]: This is a semi on-state in the area of the V/I curve where only a limited glow-current flows and the device has not yet turned on or reached the lowest impedance arc-mode.

3.1.10 glow voltage [ITU-T K.12]: The peak value of the voltage drop across the GDT when a glow current is flowing. It is sometimes called the glow-mode voltage.

3.1.11 glow-to-arc (transition) current [ITU-T K.12]: The current required for the gas discharge tube to pass from the glow-mode into the arc mode.

3.1.12 impulse waveshape [ITU-T K.12]: An impulse waveform designated as x/y has a rise time of x μs and a decay time to half value of y μs as standardized in [IEC 60060].

3.1.13 residual voltage [ITU-T K.12]: See "discharge voltage".

3.1.14 spark-over [ITU-T K.12]: An electrical breakdown of the discharge gap of a gas discharge tube. Also referred to as "breakdown".

3.1.15 spark-over voltage [ITU-T K.12]: The voltage which causes spark-over when applied across the terminals of a gas discharge tube.

- **spark-over voltage, d.c.**: The voltage at which the gas discharge tube sparks over when a slowly rising d.c. voltage up to 2 kV/s is applied.
- **spark-over voltage, impulse**: The highest voltage which appears across the terminals of a gas discharge tube in the period between the application of an impulse of given wave-shape and the time when current begins to flow.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 antenna-coupling component: Component connected from an accessible metal part to a nominal 125 V or 250 V line circuit within an appliance.

NOTE – This definition is based on the definition provided in [b-UL 1414].

3.2.2 class Y1 component: Component connected from an accessible metal part to a nominal 250 V line circuit within equipment.

NOTE – This definition is based on the definition provided in [b-UL 1414].

3.2.3 class Y2 component: Component connected from an accessible metal part to a nominal 125 V line circuit within double insulated equipment, or a component that is connected from an accessible metal part to a nominal 250 V line circuit within grounded equipment.

NOTE – This definition is based on the definition provided in [b-UL 1414].

3.2.4 modes of protection (of a voltage limiting surge protective device (SPD) or equipment port): List of terminal-pairs where the diverted surge current is directly between that terminal-pair without flowing via other terminals.

3.2.5 surge protective component (SPC): Component specifically included in a device or equipment as part of the mitigation of onward propagation of overvoltages or overcurrents or both.

NOTE – The selected component should not significantly degrade the normal system operation.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AWG American Wire Gauge

BUG Backup air Gap

GDT Gas Discharge Tube

HF High Frequency

IC Integrated Circuit

MOV Metal-Oxide Varistor

PoE Power over Ethernet

POTS Plain Old Telephone Service

PTC Positive Temperature Coefficient

SMT Surface Mount Technology

SPC Surge Protective Component

SPD Surge Protective Device

xDSL x-type Digital Subscriber Line

5 Construction

Gas discharge tubes consist of two or more metal electrodes separated by a small gap and hermetically sealed to a ceramic or glass cylinder, Figure 1 shows a 2-electrode GDT.

Figure 1 – "See-through" view of a surface mount two-electrode GDT

The cylinder is filled with a noble gas mixture. When sufficient voltage is applied to the electrodes, gas ionization is caused and spark-over occurs into a glow discharge mode and finally a low-voltage arc condition when sufficient surge current is available. When a slowly rising voltage across the gap reaches a value determined primarily by the electrode spacing, gas pressure and gas mixture, the turn-on process initiates at the spark-over (breakdown) voltage. Once spark-over occurs, various operating states are possible, depending upon the external circuitry. These states are shown in Figure 2. At currents less than the glow-to-arc transition current, a glow region exists. At low currents in the glow region, the voltage is nearly constant. Beyond this abnormal glow region the tube impedance decreases in the transition region into the low-voltage arc condition. The arc-to-glow transition current may be lower than the glow-to-arc transition. The GDT electrical characteristic, in conjunction with the external circuitry, determines the ability of the gas tube to extinguish after passage of a surge, and also determines the energy dissipated during the surge.

If the applied voltage (e.g., transient) rises rapidly, the time taken for the ionization/arc formation process may allow the transient voltage to exceed the value required for breakdown in the previous paragraph. This voltage is defined as the impulse breakdown voltage and is generally a positive function of the rate-of-rise of the applied voltage (transient).

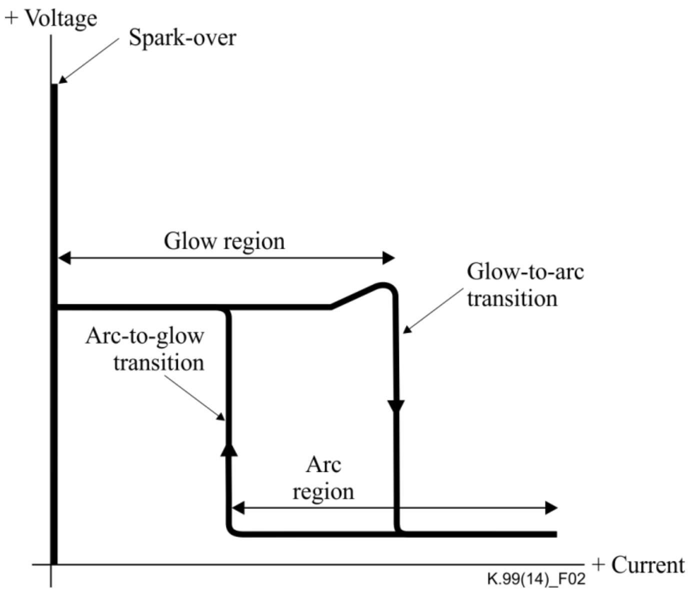

Figure 2 – Typical GDT voltampere characteristic

A single chamber 3-electrode GDT has two cavities separated by a centre ring electrode; see Figure 3. The hole in the centre electrode allows gas plasma from a conducting cavity to initiate conduction in the other cavity, even though the other cavity voltage may be below its spark-over voltage; see Figure 7.

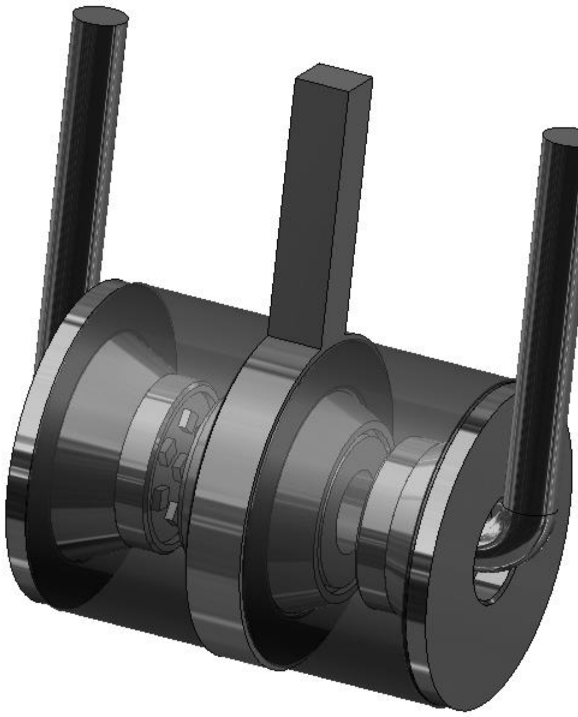

Figure 3 – "See-through" view of a leaded three-electrode GDT

Because of their switching action and rugged construction, gas tubes exceed other voltage limiting surge protective components in current-carrying capability. Many telecommunications gas tubes can easily carry surge currents as high as 20 kA, 8/20, depending on design and size values currents of > 100 kA can be achieved.

The construction of gas discharge tubes is such that they have very low capacitance, generally less than 2 pF. This allows their use in many high-frequency circuit applications.

When gas discharge tubes operate, they may generate high-frequency radiation, which can influence sensitive electronics. It is therefore wise to place GDT circuits at a certain distance from the electronics. The distance depends on the sensitivity of the electronics and how well the electronics are shielded. Another method to avoid the effect is to place the GDT in a shielded enclosure.

6 Electrical characteristics

In terms of voltage limiting performance, a GDT has four key parameters; d.c. spark-over voltage, impulse spark-over voltage, arc voltage and d.c. holdover voltage.

6.1 GDT spark-over voltage

The GDT spark-over voltage depends on the rate at which the voltage is applied.

6.1.1 d.c. and impulse spark-over voltage

The maximum value of limited voltage depends on the surge voltage rate of rise. Figure 4 shows a typical relationship between the GDT d.c. spark-over and the impulse, fast rate of voltage rise, spark-over of a GDT. In this example, the minimum 1000 V/µs spark-over voltage of 575 V occurs with a 150 V d.c. spark-over voltage GDT. The much lower voltage 75 V d.c. spark-over GDT has a 1000 V/µs spark-over voltage of 700 V – nine times higher than the d.c. value. Where fast rising transients occur, often the 150 V GDT will be more effective than a 75 V GDT, due to the gas mixture that is used to achieve a low voltage GDT.

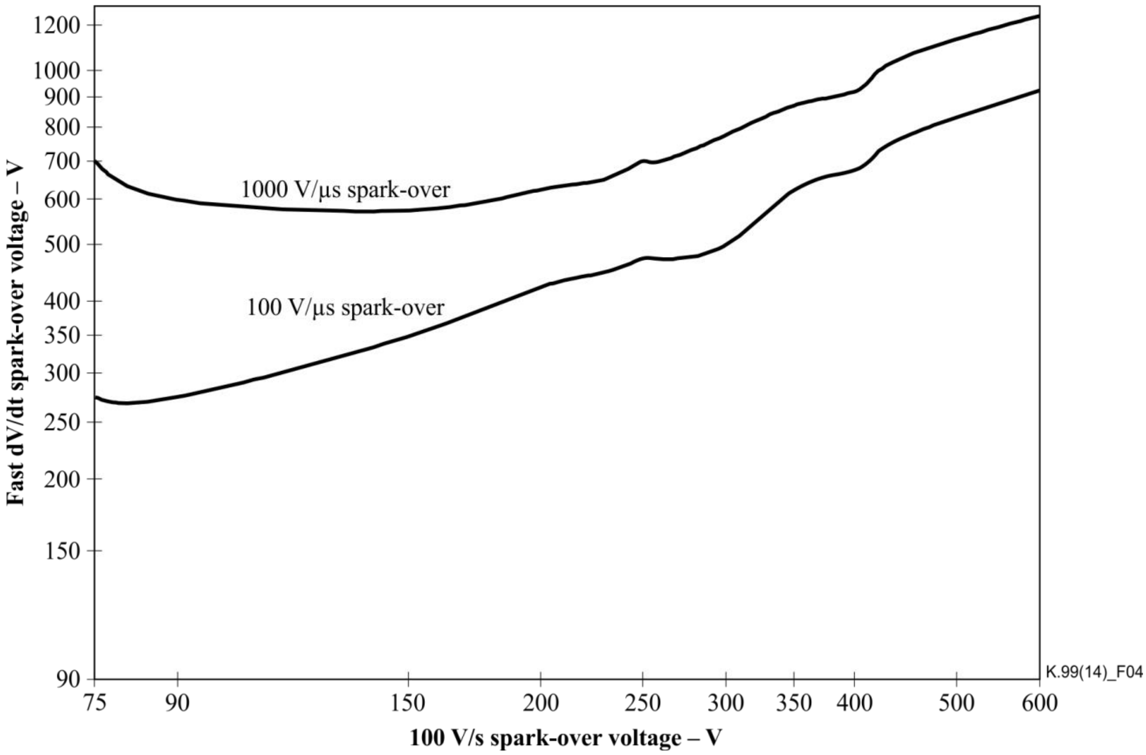

Figure 4 – Fast dv/dt spark-over voltage variation with d.c. spark-over voltage

Figure 4 shows absolute values of voltage. In terms of relative voltage increase, this factor continuously decreases with increasing voltage, being: 9x at 75 V, 4x at 150 V, 2.6x at 300 V and 2.1x at 600 V. For example, two 150 V GDTs in series could have a spark-over up to 1150 V at 1000 V/µs, but a single 300 V GDT would have a spark-over of 775 V at 1000 V/µs. These numbers are just for demonstration of GDT characteristics and may vary for different designs.

6.1.2 Spark-over voltage stability

GDTs have inherent wear out mechanisms. By selecting the appropriate GDT for an application, the desired service life can be achieved, such as 30 years for network telecommunication equipment. Prime indicators of wear out are changes to the insulation resistance and spark-over voltage. Figure 5 shows the measured change in spark-over voltage with number of impulses for the heavy duty 500 A, 10/1000 GDTs. This shows the importance of suppliers giving users assurances of not only day-one performance, but also stability over life.

Designers would like GDTs with d.c. to impulse spark-over voltage ratios as low as possible, popularly called "Fast" GDTs. "Fast" GDT formulations, with lower spark-over voltages, were designed to comply with this request. The downsides to such formulations are higher arc voltages, higher Glow to Arc transition current and more a.c. power loss. For the early versions, one European deployment, a maintenance programme had to be set up to replace a particular type of "fast" primary GDT every two years. To achieve the faster response time, some manufacturers actually had to down-grade the surge withstand capability of their GDTs. However, apart from that, "Fast" GDTs can have the same spark-over stability during their lifetime as common GDT types, see Appendix I.

Because the characteristic of a "Fast" GDT is different, it can form a relaxation oscillator with the rest of the circuit. During laboratory a.c. power fault testing, the burst of high frequency (HF) oscillation generated when the GDT sparks over often destroys x-type digital subscriber line (xDSL) driver integrated circuits (Ics). This is partly due to testing technique, as other connected equipment is decoupled to prevent diversion of the a.c. power fault current away from the equipment under the test. In an actual system, the loading from the decoupled equipment may damp out the oscillation tendency; see Figure 6.

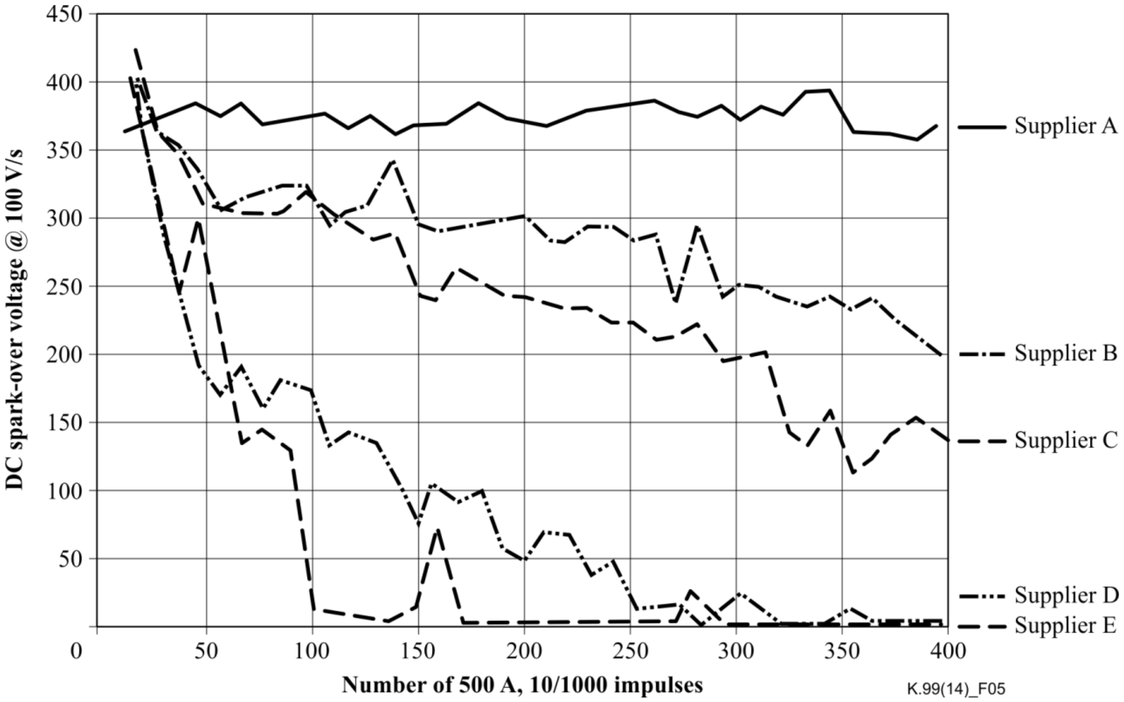

Figure 5 – 350 V GDT d.c. spark-over voltage variation with repetitive surging

6.1.3 Spark-over dark effect

Some GDT data sheets specify that the spark-over measurement is made with the GDT "In ionized mode". This means that the GDT has gas in a pre-ionized state when the spark-over voltage measurement is done. Just because a manufacturer does not state any preconditions does not mean they do not test their GDTs in a pre-ionized state.

The "dark effect" is a term that describes the difference between the non-ionized spark-over voltage and the pre-ionized spark-over voltage. A good illustration of the "dark effect" is a telecommunications repeater history. A particular repeater was failing in the field, but laboratory testing showed the repeater had excellent withstand to surges. That is, until one day the testing was done with the repeater box lid on and the repeater failed. What happened was with the lid off, light falling on the GDT pre-ionized the gas filling and resulted in a lowered spark-over voltage. When the lid was in place for a period, there was no gas pre-ionization and a much higher first surge spark-over voltage, damaging the repeater. Further spark-over measurements gave a lowered spark-over voltage, as the gas was pre-ionized from the first surge. This experience gave rise to the "dark effect" term.

GDTs were then introduced with radioactive traces in the gas filling, which pre-ionized the gas. Now radioactive GDTs are banned; new green technologies have been developed which nearly achieve the same characteristics. See Appendix II for present-day performance. Normally, to test for the dark effect, the GDT is kept in darkness for 24 hours then tested. Some manufacturers build the "dark effect" increase into their quoted spark-over voltages and test to tighter voltage levels in production (as production is not done in total darkness). The dark effect can be minimized by the internal geometry of the GDT and the emission coatings used.

6.2 GDT glow voltage

The glow voltage region influences two operational areas: d.c. holdover and low a.c. power loss. When a GDT is connected to conductors sourcing d.c. power, it is possible for a current limited d.c. source voltage to maintain the GDT in the glow region after a surge. If the glow voltage is higher than the d.c. source voltage, then latch up in the glow region cannot occur. In a.c. power fault conditions, if the current flow is limited to below that needed for a glow-to-arc transition, typically

100 mA to 1.5 A, depending on design, the GDT can have a significant power loss in this high-voltage low-current condition.

6.3 GDT arc voltage

The arc voltage influences the a.c. power fault power loss and the longer-term residual voltage applied to the protected equipment. For the best performance in both areas the arc voltage should be as low as possible. Typical GDT arc voltage ranges from 10 V to 30 V, the higher-level arc voltages usually being the result of a design compromise to enhance some other GDT parameters.

6.4 GDT d.c. holdover voltage

This is not really a GDT parameter, but the outcome of a circuit with the GDT in it. The circuit result determines if the GDT resets after a surge in a d.c. biased circuit. The three common bias voltages are 135 V (100 mA resistively limited), 80 V (200 mA resistively limited) and 52 V (260 mA resistively limited). If the GDT continues to conduct current 150 ms (typical for most standards) after the surge it fails the test.

6.5 GDT capacitance

The capacitance of a GDT is size dependent. Generally the GDT capacitance is little more than wiring stray capacitance and generally is not a major consideration in limiting the frequency response. As the lighting surge spectrum has little content over 1 MHz [b-Standler], the GDT capacitance can be decoupled from the circuit at higher frequencies by a series inductor, taking care not to create an un-damped resonant circuit in conjunction with the signal line characteristic impedance. Typically the capacitance of a GDT is a few pico Farads or less, and independent of the frequency and the applied bias voltage.

6.6 GDT oscillation

Switching-type voltage limiters such as GDTs and thyristors can form relaxation oscillators under low-current surge conditions and high circuit impedance. The oscillation frequency is a function of the switching characteristic, the circuit capacitance, the surge source impedance and the current. In a given system the occurrence of oscillation is strongly dependent on the emission coating formulation and geometrical design of the GDT used. There is a tendency for fast GDTs (lower overshoot) to be more prone to oscillation than conventional GDTs. When evaluating for GDT oscillation several manufacturers components should be assessed.

These oscillations may disrupt the operation or can damage connected equipment. Oscillation frequency can be many MHz and can propagate into adjacent cabling and equipment. GDT oscillation has become a significant field issue as a result of the conversion of plain old telephone service (POTS) lines to high impedance xDSL lines with sensitive equipment.

Laboratory testing of xDSL systems increase the possibility of oscillation as the test circuit will remove some of the natural system damping by decoupling the connected auxiliary equipment. A test with a high source impedance and low current is the 600 V rms, 600 Ω power fault test. The inductance of the a.c. source transformer means there will be little damping of oscillations in the test circuit.

Figure 6 is a power fault oscillation example reproduced from [b-Lusin]. The bottom green trace is the GDT voltage at 500 V/Div. As the a.c. voltage increases from zero, the GDT switches at its spark-over voltage of about 350 V. Initially, the GDT switches into an arc condition but after a short period, the lack of current causes oscillation between the arc and the higher glow voltage conditions. Note how the oscillation is not symmetrical between positive and negative a.c. polarities or consistent in a given polarity. These high frequency GDT oscillations couple into the twisted pair wires and appear as a large voltage between the twisted pair wires as shown by the top blue trace (20 V/Div). This powerful 80 V peak-to-peak oscillation is much higher than the normal xDSL signal and can damage the xDSL transceiver IC. The solution to this problem is either to select and specify a GDT that does not oscillate or add differential protection to the transceiver IC circuit.

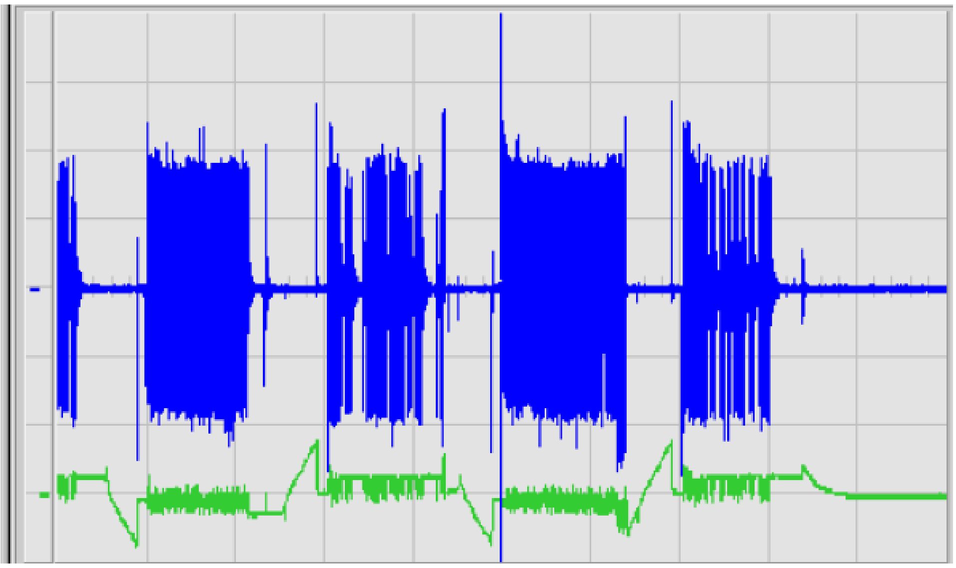

Figure 6 – GDT oscillation traces

7 Electrical ratings

7.1 GDT surge current capability

7.1.1 Maximum single impulse discharge current test

The maximum single impulse discharge current test is a measure of the capability of a GDT to withstand a single large surge. Nearby lightning strikes can produce such surges. [ITU-T K.12] specifies a 10/350 waveform. This magnitude is determined by the possibility of exposure to a severe impulse. The test is of greatest importance in applications involving exposed facilities located in areas of high lightning activity or high soil resistivity. The maximum single impulse current is mainly determined by factors such as the electrode area, the electrode material, emission coating, the heat dissipation path, etc. For an 8/20 current waveform quoted capabilities range from 5 kA to 100 kA, with a typical value of 20 kA.

7.1.2 Impulse life test

One of the most important measures of the capability of a GDT is the impulse life test. Table 5 of [ITU-T K.12] suggests the wave shapes and the currents to be used. The individual application will determine the extent of life test requirements needed.

Applications in areas of high lightning incidence or severe exposure may justify the use of GDTs with high impulse life characteristics.

Although lightning typically occurs in multiple strokes per flash, usually averaging two to six strokes within a few tenths of a second, a standardized life test method single surges has been accepted. Test results can be used for comparing cost/performance trade-offs and to indicate the durability of GDTs. Failure criteria for this test are defined in [ITU-T K.12].

The useful life of a GDT has ended when degradation results in interference with service transmission or signalling, or when the impulse breakdown voltage reaches a point where the GDT fails to protect.

7.2 a.c. discharge current test

The ability of a GDT used on communications lines to withstand an a.c. current is significant in applications where power contacts and power induction are factors. Experience has shown that induced currents are usually less than 5 A, but may be of very long duration. Power contact currents of hundreds of amperes are possible, but the high currents are usually interrupted in less than 5 s by thermally activated fail-short devices, that are typically an externally fitted part on the GDT, that short the line(s) to ground for safety, preventing thermal overload (fire hazard) of the protector and the system the protector is connected to.

8 Application examples

This clause covers the basic building blocks of GDT circuits and design techniques.

8.1 Two-electrode and three-electrode GDT comparison

Figure 7 shows the circuits and operation of a single chamber, 3-electrode GDT and two 2-electrode GDTs. It is assumed that a longitudinal surge on the R and T conductors causes the spark-over of GDT section (GDT_R and GDT1, respectively) connected to the R conductor. The waveform on the R conductor is shown as a black line in Figure 7. The R and T conductor twisted pair coupling causes the T conductor voltage to fall when the R conductor GDT sparks over. Over a period of time the conductor coupling reduces and the T conductor voltage rises (green line in Figure 7) until the spark-over voltage of GDT2 is reached. This does not happen for the 3-electrode GDT. Shortly after the spark-over of the R conductor section the T conductor section fires due to plasma from the first spark-over (blue line in Figure 7).

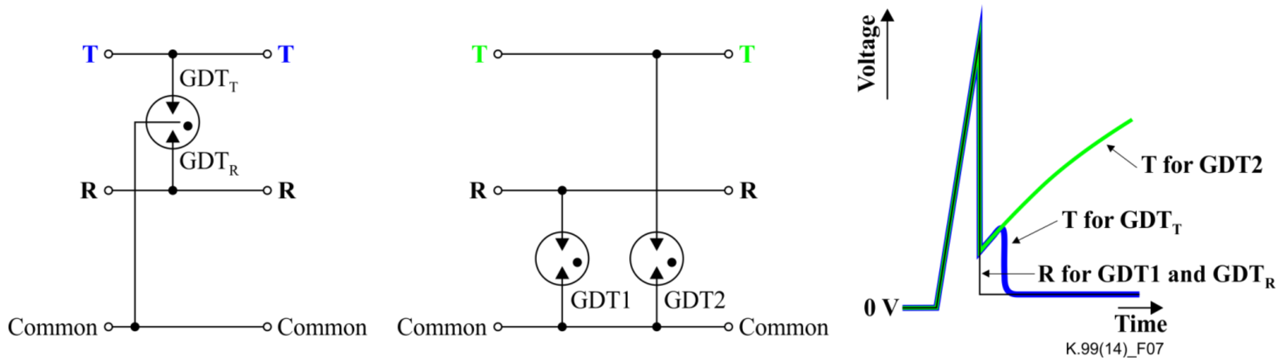

Figure 7 – Three-electrode and two-electrode GDT operation

The synchronization of the 3-electrode GDT sections, GDT_R (connected to the R conductor) and GDT_T (connected to the T conductor) switching, greatly reduces the transverse R-T voltage. It has made many service providers to mandate the use on 3-electrode GDTs to avoid the following potential problem with two 2-electrode GDTs.

Figure 8 shows a primary protector consisting of two GDTs connecting to a modem. The modem protection circuit has a thyristor overvoltage protector, Th1, to pass [b-TIA-968-A]. Fuse, F1 may be fitted or a No. 26 American wire gauge (AWG) telecommunication line wire supplied to pass power fault testing. The modem is connected between the R and T conductors, without any protection to common. In this circuit, the primary has two modes of protection and the modem has one mode of protection.

The primary protection spark-over of the two GDTs on a longitudinal impulse will not be synchronous, in this example GDT1 fires, and so a transverse R-T impulse will result. This transverse impulse is likely to operate the modem protector Th1, whose conduction will inhibit the spark-over of GDT2. The resulting current flows are shown in Figure 8. Thyristor Th1 now carriers the primary current that GDT2 should have conducted and may possibly fail. The arrangement of Figure 8 will not coordinate unless the modem Th1 protector has a higher limiting voltage than either of the GDTs. Replacing GDT1 and GDT2 with a single chamber 3-element GDT would mitigate against the primary protector generated transverse surges, but will not protect against upstream generated transverse surges.

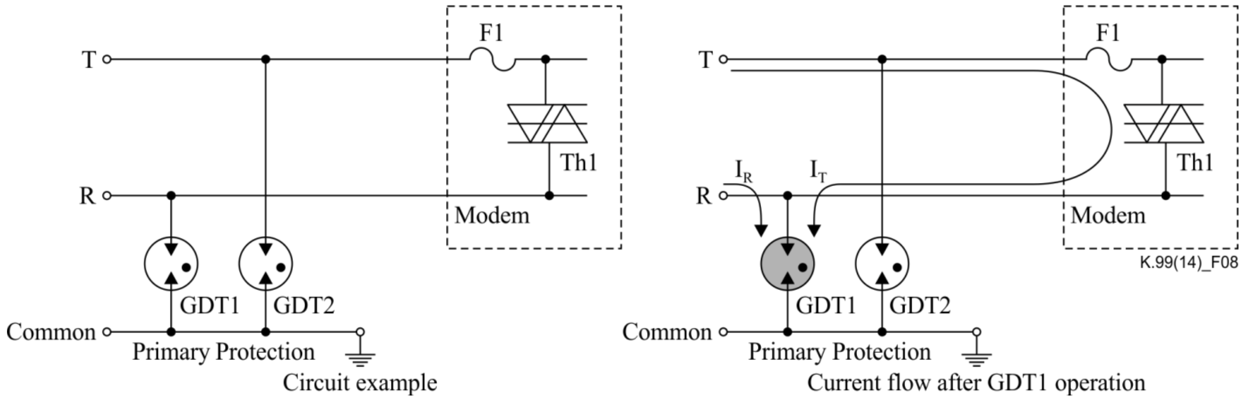

Figure 8 – Primary protector and modem

8.2 Surge bonding

In sensitive systems, the ground loops created by multiple bonding can add noise to the signal. Only having one bonding point can remove the noise, but results in high voltages at a remote signal source under surge conditions. The use of a surge bonding GDT, allows the signal source to float during normal operation, but be locally bonded during a surge condition. Figure 9 shows local and remote equipment connected by a screened cable carrying the signal pair. When a surge causes the cable screen voltage at the remote equipment to exceed the GDT spark-over voltage, the GDT conducts, bonding the screen to the remote equipment local ground. To obtain lower surge voltage bonding level a parallel GDT metal-oxide varistor (MOV) (hybrid) combination could be used.

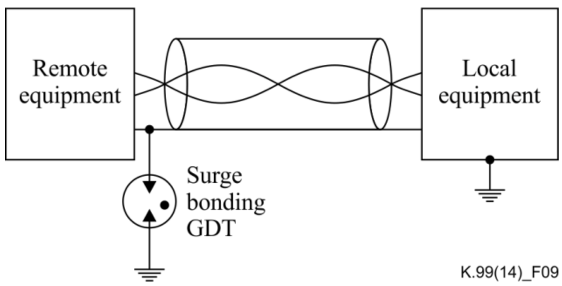

Figure 9 – GDT ground bonding during surge

8.3 GDT pass under protection for a.c. fault conditions

In certain applications, it is desirable to have the GDT operate under impulse conditions, but not under a.c. power fault conditions. Such an arrangement allows the a.c. test voltage to pass under the GDT d.c. spark-over voltage. For example, Australia uses a 900 V GDT to avoid high levels of a.c. in the feed wire at customer premises.

To avoid a.c. conduction during a 600 V rms equipment power fault test, the minimum GDT d.c. spark-over voltage must exceed 850 V. Allowing a ±20% tolerance on the nominal GDT d.c. spark-over voltage, a 1100 V GDT would be required, see Figure 10. The shunting modem transformer, T, and series d.c. blocking capacitor, C, must also withstand the 600 V rms.

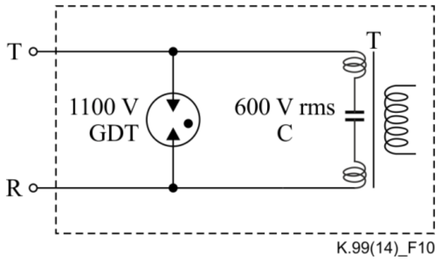

Figure 10 – Modem "pass under" interface design to avoid 600 V a.c. current conduction

8.4 GDTs in a.c. mains applications

GDT with series MOV pass under designs can be used in audio, video and musical instrument equipment [b-UL 6500] for the following applications:

a) Across-the-line GDT/MOV recognized combination provides basic insulation at 125 V a.c. and 250 V a.c.

b) Antenna coupling GDT/MOV recognized combination provides basic insulation at 125 V a.c. and 250 V a.c.

c) Class Y1 GDT/MOV recognized combination provides reinforced insulation at 125 V a.c. and 250 V a.c.

d) Class Y2 GDT/MOV recognized combination provides reinforced insulation at 125 V a.c. and 250 V a.c.

e) Line bypass GTD/MOV recognized combination provides basic insulation at 125 V a.c. and 250 V a.c.

The components for these applications must be recognized to have sufficient withstand capabilities as premature spark-over might result in a risk of fire, electric shock or injury to persons [b-UL 1449]. Y1 applications require that the GDT does not spark-over when 4000 V rms, 60 Hz is applied for 1 minute (d.c. spark-over must be greater than 5660 V). Y2 applications require that the GDT does not spark-over when 2000 V rms, 60 Hz is applied for 1 minute (d.c. spark-over must be greater than 2830 V). The insulation breakdown voltage of the equipment using these GDTs under designs must be greater than the maximum GDT impulse spark-over voltage. For Y2 applications, the equipment insulation breakdown voltage probably needs to exceed 4 kV.

8.5 Hybrid protectors

Hybrid protectors are two-terminal or three-terminal combinations of different technologies to overcome a deficiency of a single technology.

8.5.1 GDT-MOV parallel hybrid

This GDT-MOV hybrid is a combination of switching and clamping voltage-limiting elements. The parallel connection of a GDT and MOV reduces the GDT limiting-voltage overshoot at high rates of voltage rise. Figure 11 shows the circuit and voltage reduction due to the addition of the MOV.

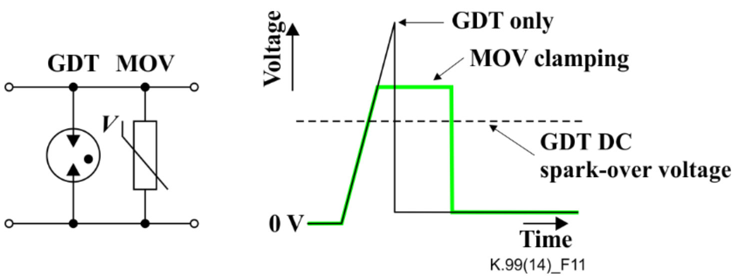

Figure 11 – Parallel GDT–MOV hybrid

The MOV clamping action delays the GDT spark-over, but it reduces the peak limiting voltage to a lower value. For the GDT to spark-over, the downstream circuit must withstand and develop at least the GDT d.c. spark-over voltage level. A bidirectional avalanche diode may be used instead of a MOV to perform the clamping function, but the avalanche diode will have a higher capacitance than the MOV, which could be a problem in broadband circuits. The MOV clamping voltage must be chosen so that it is never below the GDT d.c. spark-over voltage, otherwise GDT operation would be prevented and the MOV would be subjected to the full surge and possibly fail. Making the MOV clamping voltage much higher than the GDT d.c. spark-over value will result in higher peak let-through voltages before the GDT sparks over. A higher voltage MOV will also have a lower capacitance value due to both the higher voltage and lower required energy capability. The performance of a hybrid depends on the characteristics of the GDT and the clamping energy (size) of the MOV. One manufacture reports a capacitance of 35 pF and a 600 V spark-over voltage at 1000 V/µs, another reports a capacitance of 20 pF and a 650 V spark-over voltage at 1000 V/µs. Changes of the GDT spark-over voltage during service must also be factored in.

8.5.2 GDT-MOV series hybrid

Connecting a GDT and MOV in series would be expected to give a limiting voltage equal to the sum of the individual component limiting voltages; see Figure 12. At low frequencies this is a reasonable approximation, except it should be remembered that an MOV is a variable resistor. Normally the MOV resistance will be sufficiently high to prevent the GDT passing sufficient current to fully switch. Only when the voltage across the combination equals the sum of the GDT glow voltage and the MOV clamp voltage can the GDT switch into the arc mode.

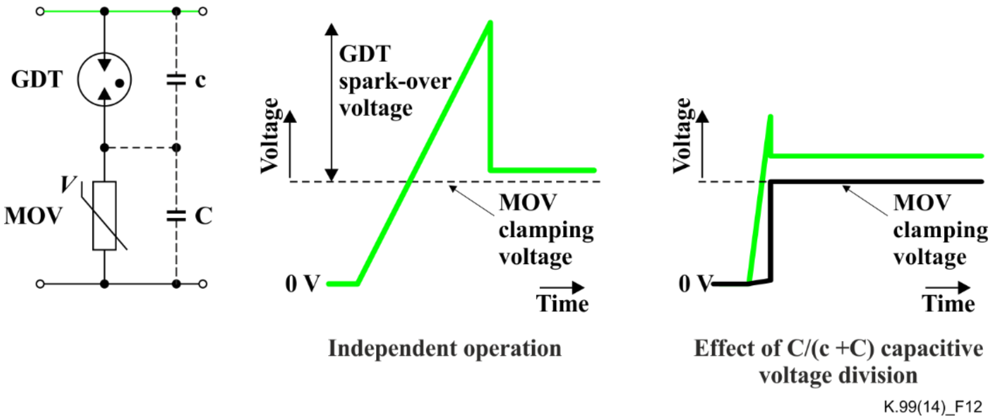

Figure 12 – Series GDT–MOV hybrid

At high rates of the voltage ramp, the situation is different due to the GDT and MOV capacitances. The GDT has a relatively small capacitance, c, compared to the MOV capacitance, C. The voltage ramp is capacitively divided across the GDT and the MOV, with the most of the voltage ramp appearing across the GDT. When the GDT switches, it charges the MOV capacitance and the MOV starts to clamp; see Figure 12. The GDT spark-over voltage needs to be higher than the MOV clamping voltage to ensure that GDT switching causes substantial MOV current. In this conducting condition, the combination limiting voltage will be approximately the MOV clamping voltage.

This type of hybrid combination is used extensively for a.c. protection. To cope with the loss of neutral situation for 120 V a.c. systems, the sum of the GDT and MOV voltages needs to exceed twice 120 V a.c. or 340 V peak. A single 400 V MOV would have a high limiting voltage for transients on the 120 V a.c. supply. The series GDT MOV combination gives a much lower clamping voltage than a single MOV. The MOV causes automatic non-conduction of the GDT (extinguishing of the GDT) when the combination of a.c. and transient voltage falls below the MOV clamping voltage.

An MOV is a variable resistor (hence the name "Varistor") and it will draw current and consume energy whenever there is voltage across it. Incorporating a series GDT prevents the normal MOV non-clamping current flow and results in a protection solution with effectively zero standby energy consumption.

8.6 GDT thermal switch hybrid

These switches are thermally activated mechanical shorting mechanisms mounted on the GDT, the two forming a single surge protective component (SPC). Typically the switches have a one-shot, non-resetting, action. There are three common switch technologies; melting plastic insulator and melting solder pellet or a true mechanical switch. Operation occurs as a result of the temperature rise of the GDT when exposed to long term a.c. The GDT power loss and hence rate of temperature rise is related to the arc voltage value. A 15 V arc voltage and 10 A rms will create a power loss of about 135 W. When the switch operates, it shorts out the GDT, typically to ground, and conducts the a.c. previously flowing through the GDT. The operation of the three types is as follows:

1) A plastic-melting based switch, consists of a spring with a plastic insulator that separates the spring contact from the metallic conductors of the GDT. When the plastic melts, the spring contacts both conductors and shorts out the GDT electrodes. This approach is typically used with three electrode GDTs.
2) A solder-pellet-melting based switch, consists of a spring mechanism that separates the line conductor(s) from the ground conductor by a solder pellet. In the event of a thermal overload condition the solder pellet melts and shorts out the GDT electrodes.
3) A true mechanical switch typically uses a spring assembly that is held in the open position by a soldered connection and will short out the GDT when its switching temperature is reached. When the solder melts the switch is released and shorts out the GDT electrodes. This approach is typically used with three electrode GDTs.

The plastic-melting switch mechanism can operate independently on each side when used with 3-electrode GDT. A true mechanical switch has low contact resistance and prevents a switch reopening. Solder pellet switch designs, with an inappropriate alloy, can reopen. Such solder pellet designs under high current, negative ambient temperature conditions can operate, but open again when the ambient temperature rises. These potential drawbacks make true mechanical switches, with simultaneous shorting of both line electrodes, a preferred approach; see Figure 13.

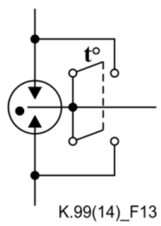

Figure 13 – Three-electrode GDT with a common thermal switch action

The speed of switch operation or conversely the a.c. withstand time, depends on the GDT arc voltage value. A 10 V arc voltage GDT will have a greater resistance to spurious switch operation than a 30 V GDT.

8.7 GDT backup air gap hybrid

When GDTs became popular in the 1960s and 1970s, US telecommunications providers became concerned about GDTs leaking or venting their gas filling, resulting in a large increase in spark-over voltage. Conventional protection up to that time was provided by carbon-air-gaps that had a typical electrode spacing (spark gap) of 3 mil (0.8 mm), providing a maximum spark-over voltage of about 1000 V.

Telecom providers were worried that the wider spaced GDT, when vented, could allow much higher voltage exposure to the telecom equipment.

The solution proposed was to have a parallel backup air gap (BUG) with a 3 mil spacing to limit the voltage to the same level as a carbon block gap would have done, in case the GDT vented. The backup mechanism was standardized for arrester assemblies requiring that a gas tube type arrester assembly shall use a secondary backup air gap or other secondary overvoltage protection mechanism that operates in the event the gas tube vents its gas.

The deployment of the BUG solution to GDT venting is still being used by some manufacturers, but is prone to contamination of particles or dust, causing premature failure. Contamination ingress lowers the BUG spark-over voltage, causing the BUG to operate on surges rather than the GDT. Another possible problem is the cross-over of impulse response between the GDT and BUG. At the fast rates of voltage rise the BUG spark-over voltage could fall below the GDT spark-over, causing the BUG to operate on the fast voltage surges, rather than the GDT. In both cases, operation of the BUG creates additional gap contamination, leading to premature failure of the hybrid protectors.

Today a "Gas Tube Seal Test Program" covers the perceived venting problem [b-UL 497]. This program tests a 300-sample lot to mechanical stress, thermal ageing, thermal shock, service life and over-pressure shock. In all cases, the spark-over voltage must be maintained. Approved manufacturers will often quote an Underwriters Laboratories (UL) file number or simply refer to the GDTs as "BUG-less".

Incorporating a BUG into a surge protective device (SPD) and the resultant reliability problem was essentially a US phenomenon. As a result, the rest of the world did not regard the loss of GDT sealing as such a major concern. [ITU-T K.12] covers sealing integrity by requiring conformance to [b-IEC 60068-2-17] test Qk, severity 600 hours.

8.8 Cascaded protection

This clause covers multistage or cascaded protector combinations.

8.8.1 Cascaded primary protection

The cascaded protector is a coordinated sub-system, where each overvoltage protection stage is coupled via a coordinating element. Figure 14 shows a typical primary protector example.

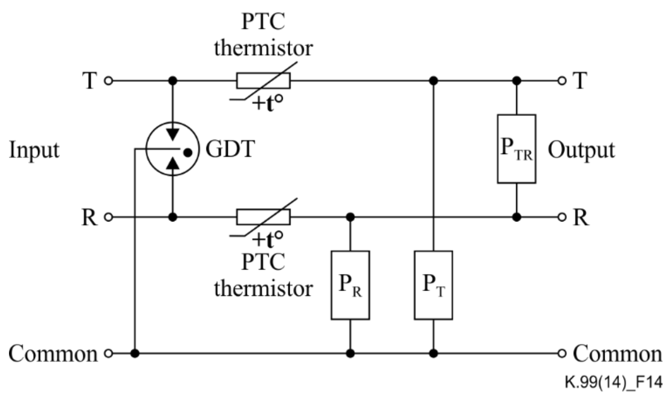

Figure 14 – Cascaded primary protection example

In this design, the input GDT protector handles the high current surges. Positive temperature coefficient (PTC) thermistors form the coordination elements between the input and output protection as well as providing an a.c. current-limiting function. Output protection can be the 3-mode illustrated or 2-mode (P_R and P_T) or single mode (P_{TR}). Various technologies can be used for the output protection; MOV, silicon avalanche diode or a bridged SPC.

Correctly designed and matched, such a primary protector can provide system coordination. The protector output short-circuit current (I_{TC}, I_{RC} and I_{TR}) and open circuit voltage (V_{TC}, V_{RC} and V_{TR}) needs to be characterized for the required impulse waveshapes over a range of input amplitudes. Low-impedance equipment must be able withstanding the protector output short-circuit current waveforms and high-impedance equipment the output open-circuit voltage waveforms. For example, equipment with a transformer interface between R and T and without protection to common should withstand the protector short-circuit current I_{TR} waveform into R and T and the open-circuit voltage V_{TC}, V_{RC} waveforms across R and T to common. Intermediate impedance equipment can be conservatively used if it develops on the appropriate terminal pair protector open-circuit voltage whilst drawing less than the terminal pair short-circuit current.

For equipment without coordination elements, but with voltage limiting, the circuit of Figure 14 without protectors P_R, P_T and P_{TR} can be used to provide system protection coordination.

8.9 Series connected GDTs for d.c. power applications

Once a GDT is in the arc mode, it will only stop conducting when the available d.c. is below the d.c. holdover level. To prevent continued conduction in high-current 48 V d.c. supply applications, several GDTs may be connected in series so that the sum of the arc voltages exceeds the d.c. supply voltage. Having a combined arc voltage that exceeds the supply ensures that the d.c. supply cannot provide current to the GDTs that would maintain conduction.

Simply connecting GDTs in series will result in a summation of the spark-over voltages and arc voltages, see Figure 15. If the GDTs 1 through 5 were matched and each had 350 V spark-over voltage and a 12 V arc voltage, then the assembly would have spark-over voltage of 1750 V (5 × 350) and an arc voltage of 60 V (5 × 12).

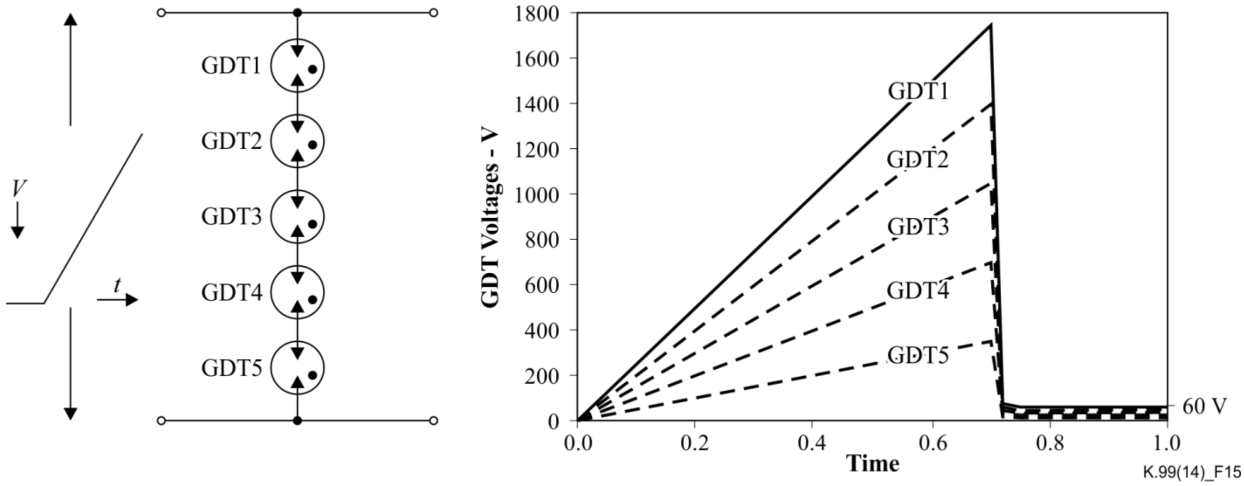

Figure 15 – Series connected GDT spark-over operation

This extremely high spark-over voltage can be reduced by the connection of decoupling capacitors to the GDT interconnections as shown in Figure 16. The following is a simplistic description of the operating sequence. As before, the GDT spark-over and arc voltages are 350 V and 12 V. The capacitors, C1 through C4, are of equal capacitance and are much higher than the GDT capacitance. Typically, the capacitor values will be in the 100 pF to 1 nF range. Initially all the component voltages are zero. As the applied voltage ramp rises there will be a capacitive voltage division across GDT1 and capacitor C1. Most of the ramp voltage will appear across GDT1. When the voltage across GDT1 reaches 350 V, spark-over occurs and the voltage across GDT1 drops to 12 V. As a result, capacitor C1 is charged to 350 − 12 = 338 V and applies this to GDT2. As the ramp continues to rise, the voltage across GDT2 will reach 350 V, spark-over occurs and the voltage across GDT2 drops to 12 V. As a result, capacitor C2 is charged to 350 − 12 = 338 V and applies this to GDT3. This sequence is repeated with GDT3 and capacitor C3, then GDT4 and capacitor C4 until finally GDT5 sparks over into a 12 V arc condition.

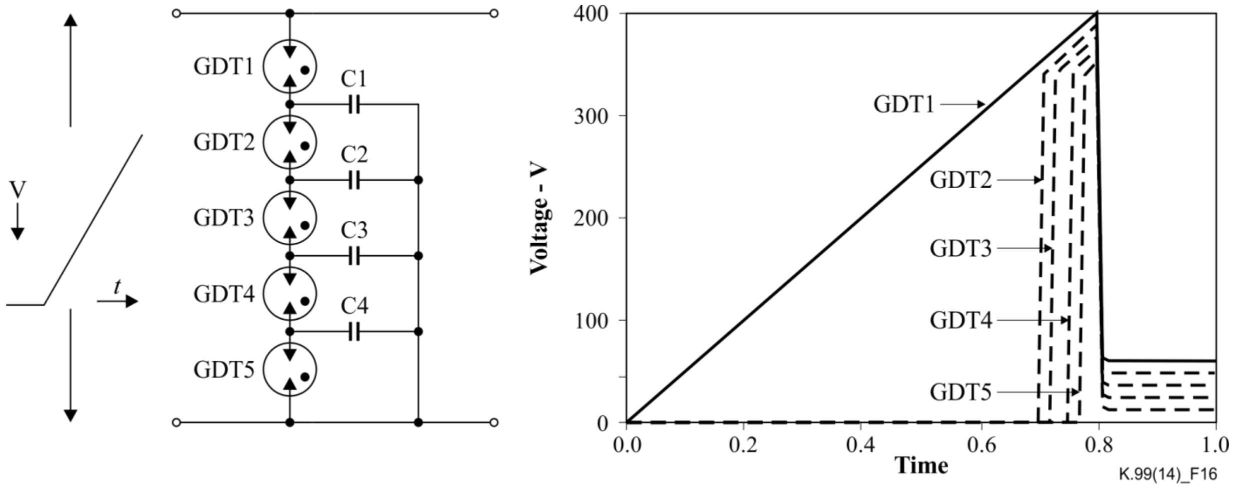

Figure 16 – Series connected GDT spark-over operation with shunt capacitors

The maximum limiting voltage of this arrangement is the 350 V spark-over voltage of GDT5 plus 48 V from the conduction voltages of GDT1 through to GDT4.

Appendix I

Durability test using "Fast" GDTs

(This appendix does not form an integral part of this Recommendation.)

I.1 Testing

I.1.1 General

Three groups (A, B, C) with different types of "Fast" GDTs were subjected to a durability test with surges of 500 A, wave shape 10/1000, 400 times.

Group of samples	d.c. breakdown	No. electrodes	dimensions
A	350 V	3	8 × 10 mm
B	350 V	3	8.4 × 13.4 mm
C	400 V	2	6 × 8 mm

I.1.2 Spark-over voltage tests

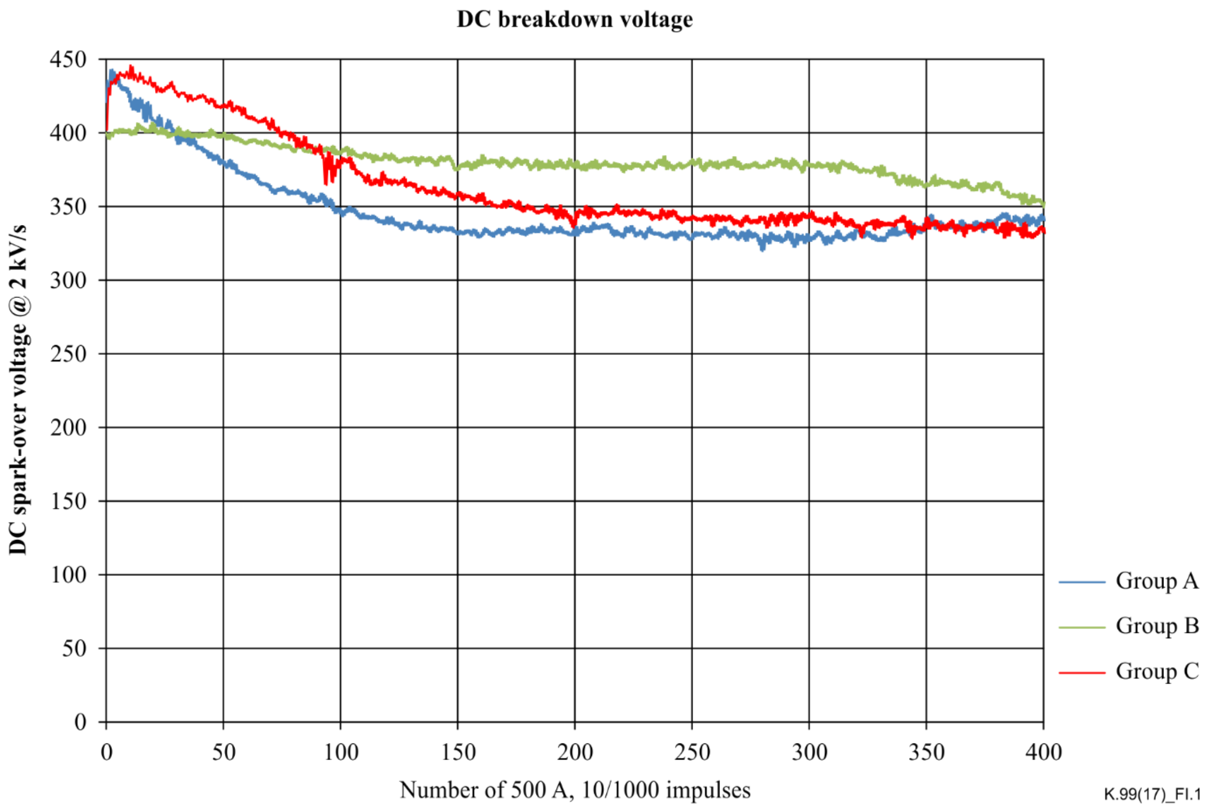

Figure I.1 – d.c. spark-over voltage variations with repetitive surging

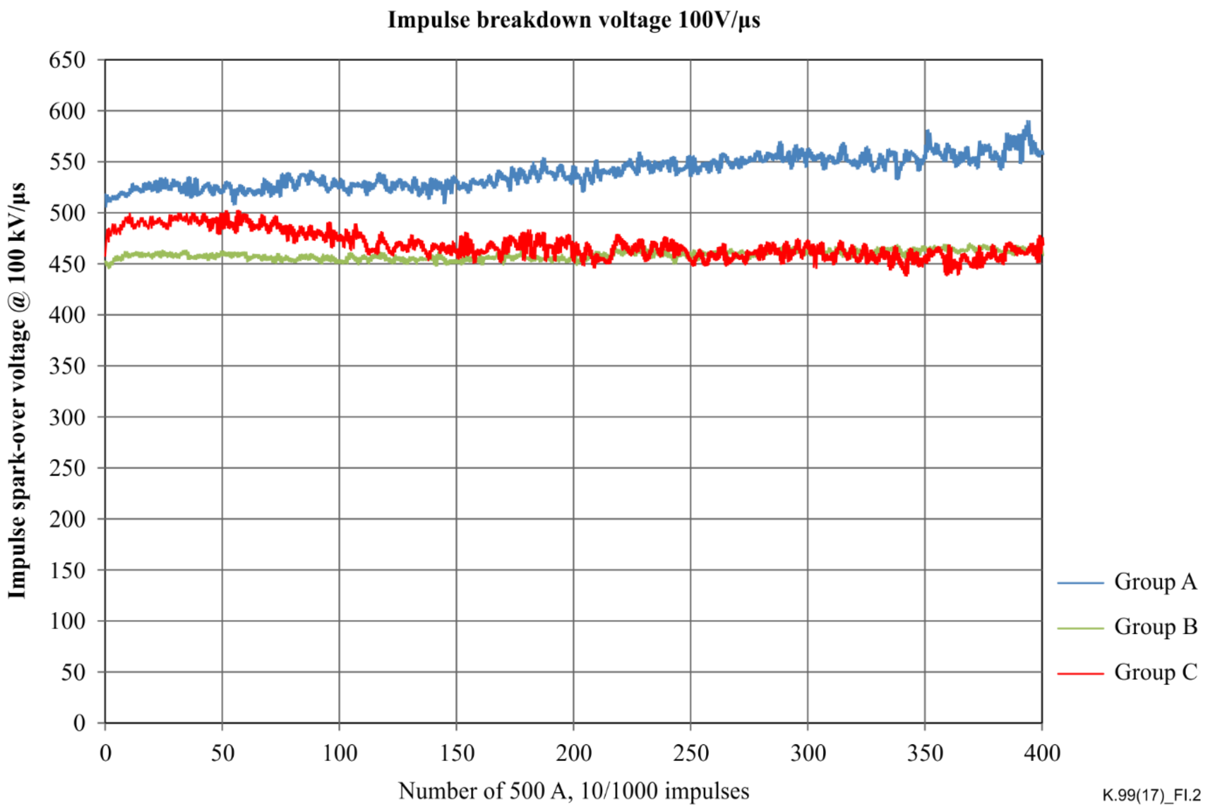

Figure I.2 – Impulse spark-over voltage variation with repetitive surging

The measurements of d.c. breakdown voltage and impulse breakdown voltage were taken after each surge. Figure I.1 shows that the change of d.c. spark-over voltage during durability testing was about 50 V. According to Figure I.2, the increase in impulse spark-over voltage during durability testing was up to 100 V. These values represent expected results.

Appendix II

Spark-over dark effect

(This appendix does not form an integral part of this Recommendation.)

II.1 Testing

II.1.1 General

Two groups (A, B) with different types of GDTs were tested in ionized mode and then again in darkness after 24 h in dark storage.

Group of samples	d.c. breakdown	No. electrodes	dimensions
A	350 V	3	8 × 10 mm
B	230 V	2	6 × 8 mm

II.1.2 Spark-over dark effect tests

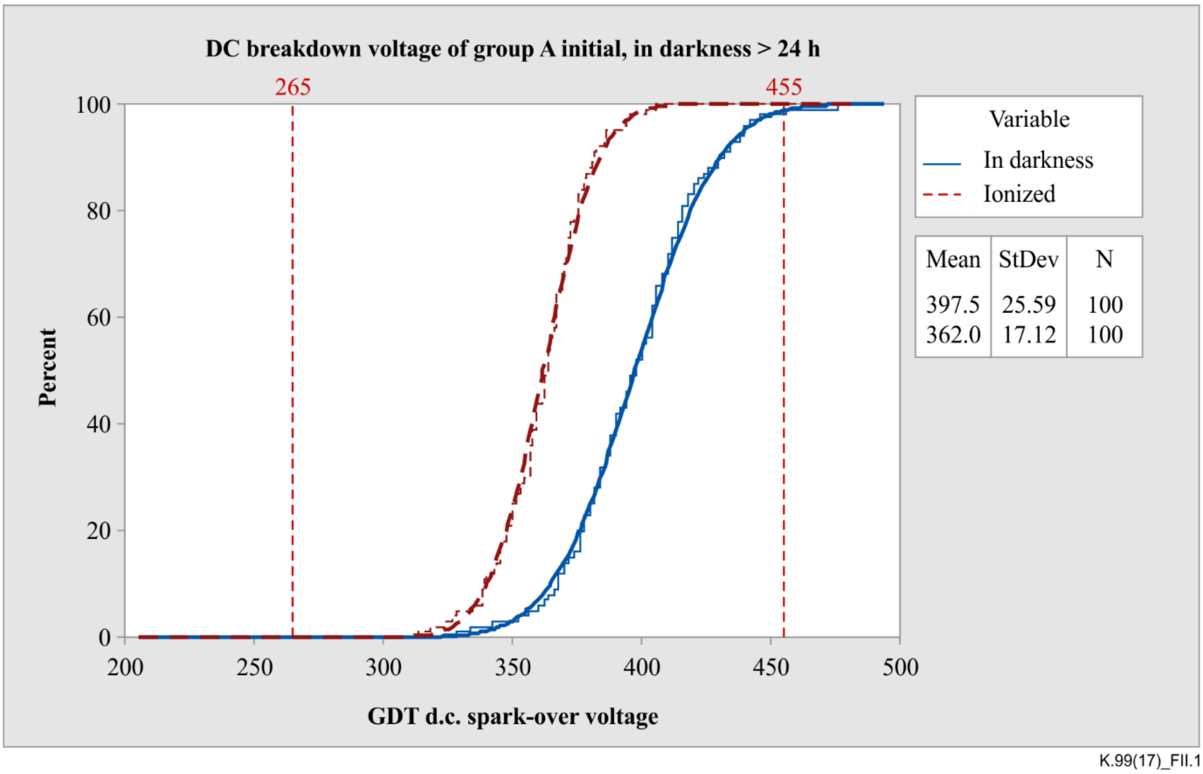

Figure II.1 – d.c. breakdown voltage group A deviation between ionized mode and after 24 h darkness

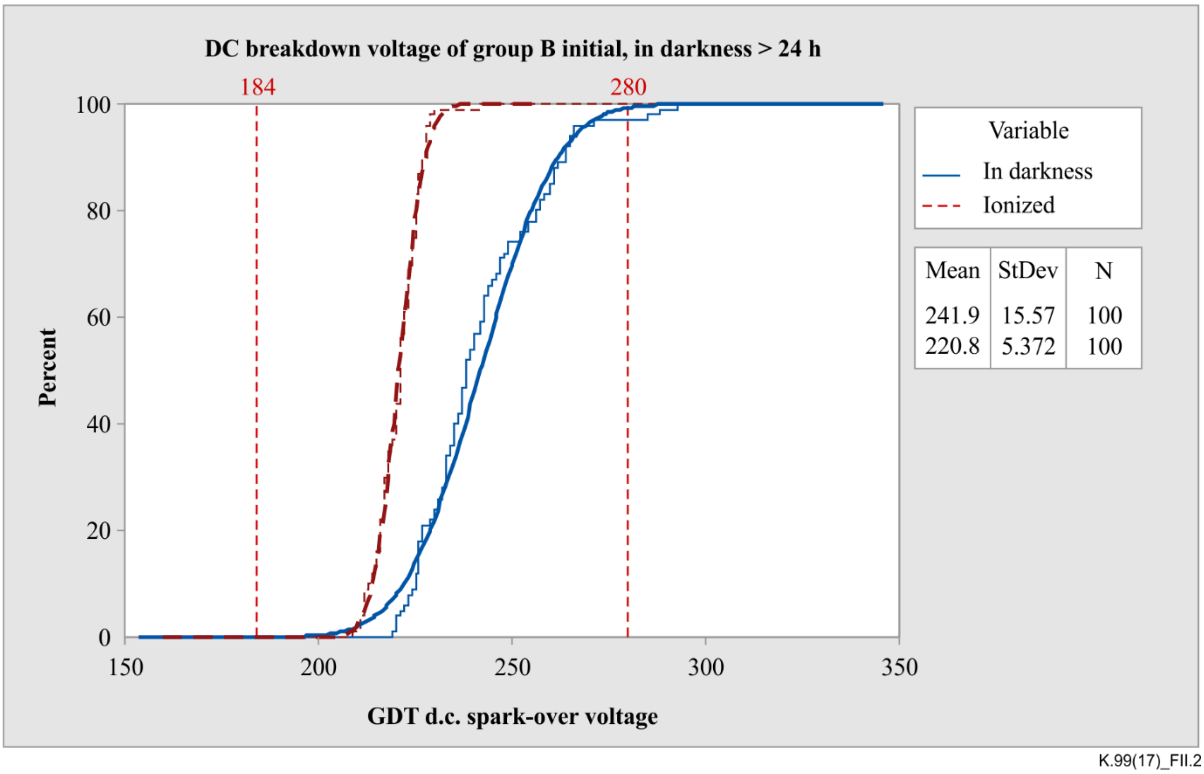

Figure II.2 – d.c. breakdown voltage group B deviation between ionized mode and after 24 h darkness

Present-day technology cannot completely eliminate the "dark effect", but the 50% mean difference between ionized and non-ionized mode was about as low as 35 V for group A, and 21 V for group B.

Appendix III

GDT component form factors

(This appendix does not form an integral part of this Recommendation.)

III.1 Introduction

GDT manufacturers have introduced GDTs with different body form factors compared to the wired terminal cylindrical shape, to satisfy customer's new assembly and height requirements.

For PCB mounted GDTs, the main form factor parameters are PCB footprint, GDT height and mounting method.

Metal electrodes brazed to an insulating ceramic to create a hermetically sealed enclosure, typically containing a noble gas. Performance enhancements can be achieved with different electrode emission coatings, electrode geometry and field enhancing additives, typically applied to the enclosure. Different form factor designs occur to satisfy applications needs and assembly techniques. The miniaturization of electronic equipment designs requires higher density circuit boards. Smaller device packages are key to enabling such miniaturization. However, these higher densities can lead to increased susceptibility to damage from transients such as lightning and other high voltage surges. This trend presents a challenge to circuit protection device manufacturers to create smaller protection solutions while maintaining robust protection. Until now, designers needing the robust performance of GDTs in their designs, had to accommodate their relatively large profile, volume and/or weight. In this Recommendation, different form factors are discussed that open new possibilities of efficient designs, while maintaining the robust GDT circuit protection performance.

GDTs can be mounted as through-hole devices or with surface mount technology (SMT). GDTs made in SMT have a flat surface that will provide better contact with the conductive pattern.

This appendix contains the following clauses:

– III.2, Outlines of GDTs with different form factors;
– III.3, Outline of GDTs with coaxial form factors;
– III.4, Outlines of GDTs with reduced axial length and 2-electrodes;
– III.5, Outlines of GDTs with reduced axial length and 3-electrodes.

III.2 Outlines of GDTs with different form factors

Typical outlines of GDTs, with different form factors, are shown in Figures III.2.1 through III.2.9 below. Figures III.2.1 through III.2.3 show miniature designs, i.e., extremely compact designs.

Figure III.2.1 – Two-electrode square GDT (SMT)

The Figure III.2.1 outline is of a square GDT; these are found in different sizes, e.g.:

– 4.5 mm × 3.2 mm × 2.7 mm (width × depth × height), with typical current rating of 2 kA (8/20 × 10);

– 3.2 mm × 1.6 mm × 1.6 mm (width × depth × height), with typical current rating of 500 A (8/20 × 10).

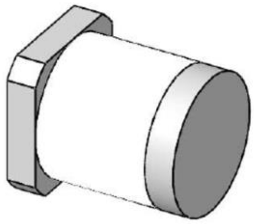

Figure III.2.2 – Two-electrode miniature GDT (SMT)

The Figure III.2.2 outline is a miniature SMT of cylindrical size 3.5 mm × Ø2.8 mm, and of typical current rating of 1 kA (8/20 × 10).

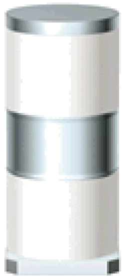

Figure III.2.3 – Three-electrode miniature GDT (SMT)

The Figure III.2.3 outline is a miniature SMT of cylindrical size 6.8 mm × Ø3.5 mm, and of typical total current rating through centre electrode of 2 kA (8/20 × 10).

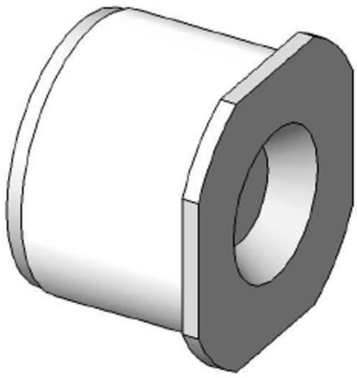

Figure III.2.4 – Two-electrode standard size GDT (SMT)

The Figure III.2.4 outline is a typical design of a GDT in SMT, with electrodes located opposite of each other and cylindrical shape. This GDT may be designed with high current rating and stable performance over its life. The standard size is 6 mm × Ø8 mm and a typical current rating is 20 kA (8/20 × 10).

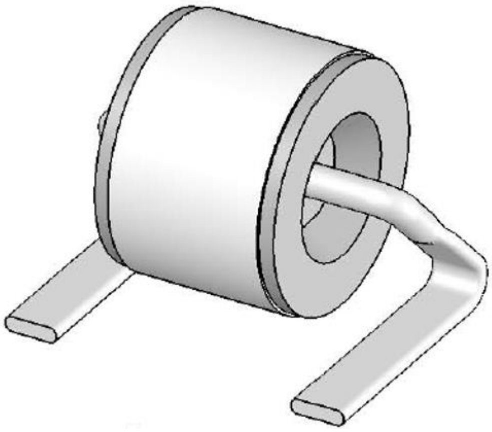

Figure III.2.5 – Two-electrode standard size GDT (SMT)

The Figure III.2.5 outline is an axial leaded cylindrical GDT with the leads formed for SMT mounting of size 6 mm × Ø8 mm and typical current rating of 20 kA (8/20 × 10).

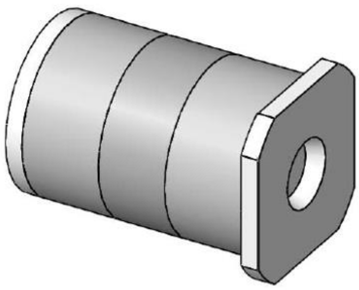

Figure III.2.6 – Three-electrode SMT configuration GDT

The Figure III.2.6 GDT outline is suitable for twisted pair protection in telecommunications equipment. A typical size is 7 mm × Ø5 mm and typical total current rating through centre electrode is 10 kA (8/20 × 10).

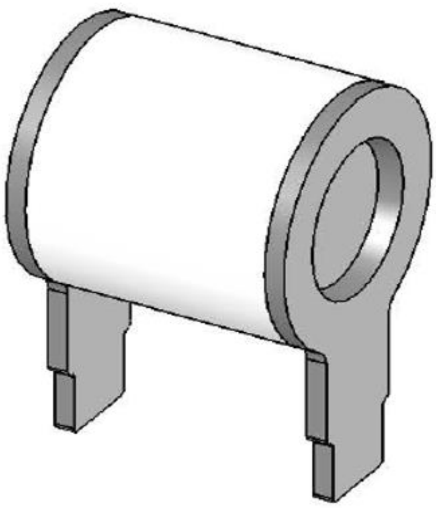

Figure III.2.7 – Two-electrode heavy duty tab terminal GDT

For increased current capability, the GDT outline in Figure III.2.7 has high current tab terminals, allowing for its use in applications such as temporary bonding of the N and PE conductors of the a.c.

mains during a lightning event. The tip of the tab shown is suitable for through-hole mounting, other tip shapes make the GDT suitable for magazine insertion. A typical size is 13 mm × Ø12 mm with typical current ratings of up to 40 kA (8/20 × 10).

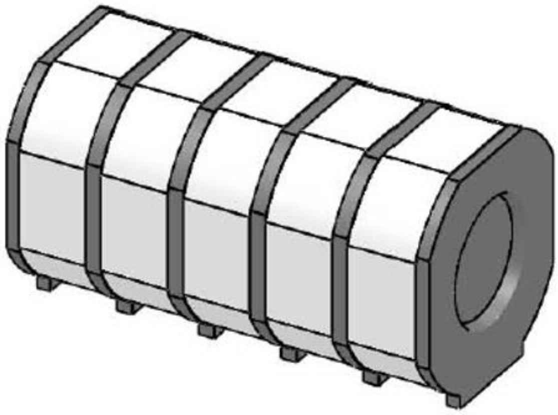

Figure III.2.8 – Five-series connected (stacked) GDT (SMT)

The Figure III.2.8 outline is of a GDT with series connected GDTs for d.c. power applications, as described in clause 8.9. A typical size is 16 mm × Ø9 mm with a current rating of 20 kA (8/20 × 10).

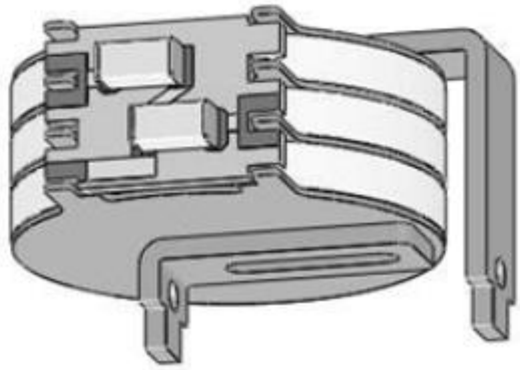

Figure III.2.9 – Three-series connected GDT

The GDT outline in Figure III.2.9 has been designed specifically for a.c. protection. A typical size is 13.7 mm × Ø31 mm with a current rating of 25 kA (8/20 × 10).

III.3 Outline of GDTs with coaxial form factors

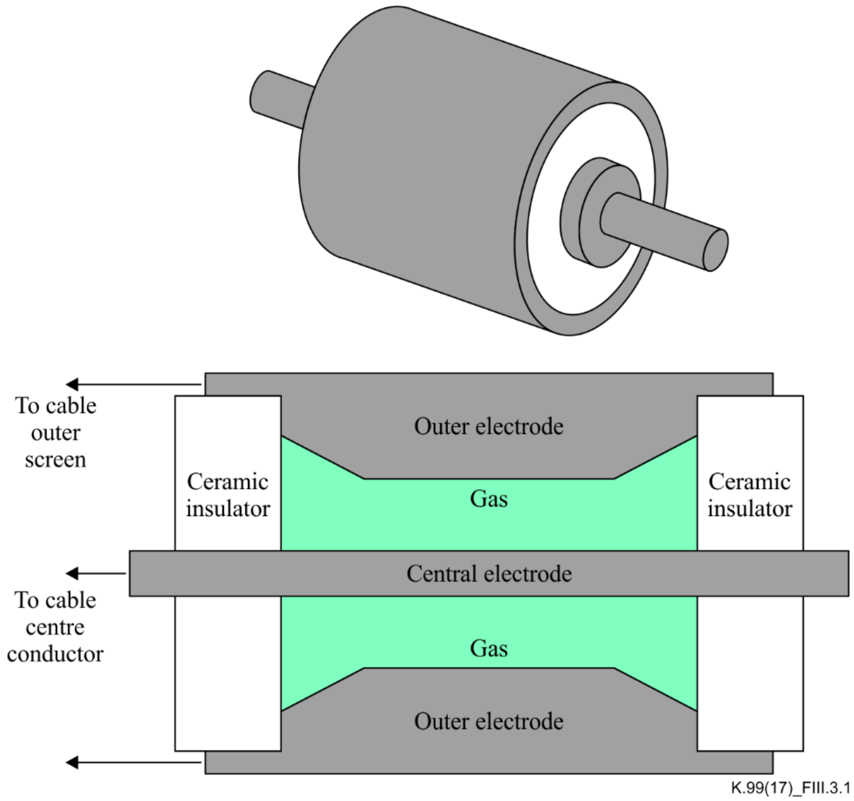

Figure III.3.1 – Two-electrode in line coaxial GDT

The Figure III.3.1 outline illustrates a coaxial form factor GDT.

Coaxial cables have characteristic impedance called Z_0. The value of Z_0 is given by:

$$Z_0 = \frac{138}{\sqrt{\mu_r \varepsilon_r}} \times log\left(\frac{D}{d}\right) \quad \Omega$$

where:

d = diameter of coaxial cable inner conductor

D = diameter of coaxial cable outer conductor

ε_r = relative dielectric constant

μ_r = relative permeability.

The value of the cable dielectric, ε_r, is typically in the range of 1.5 to 3. The ε_r value for the gas filling of a GDT is close to 1. Making a coaxial GDT with the same D/d ratio as the cable would make the coaxial GDT have a higher value of Z_0 than that of the cable. The GDT Z_0 can be made the same as the cable by reducing the outer diameter, D, see Figure III.2.9.

Typical sizes, body 6 mm × Ø6 mm with pins of 3 mm × Ø1 mm and a typical current rating of 5 kA (8/20 × 10).

III.4 Outlines of GDTs with reduced axial length and two-electrodes

Typical outlines of GDTs with reduced axial length, and 2-electrodes for applications with space constrains are shown in Figures III.4.1 through III.4.4.

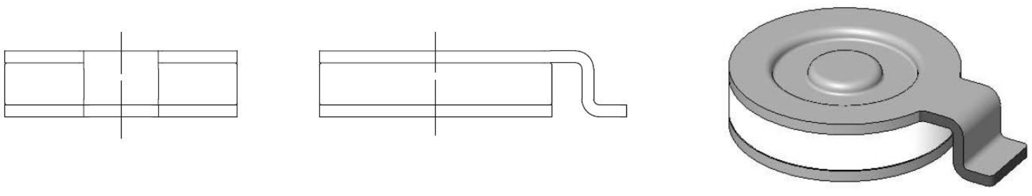

Figure III.4.1 – Two-electrode GDT with reduced axial length for horizontal SMT

Dimensions for 2-electrode GDTs, shown in Figure III.4.1, are 2.2 mm × Ø8 mm with a typical current rating of 15 kA (8/20 × 10).

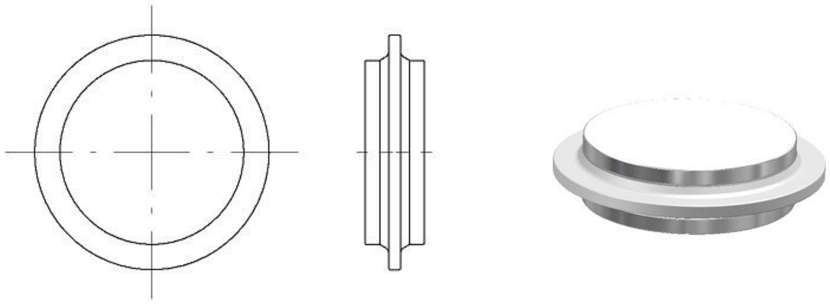

Figure III.4.2 – Two-electrode GDT with reduced axial length for cartridge designs

Dimensions for 2-electrode GDTs, shown in Figure III.4.2, are 2 mm × Ø8 mm with a typical current rating of 10 kA (8/20 × 10).

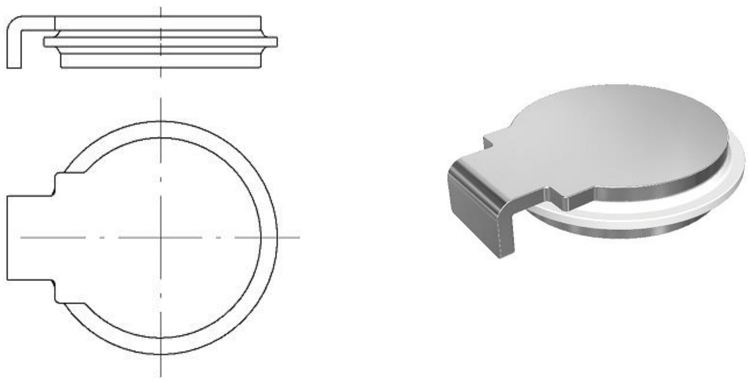

Figure III.4.3 – Two-electrode GDT with reduced axial length for horizontal SMT

Dimensions for 2-electrode GDTs, shown in Figure III.4.3, are 2 mm × Ø8 mm with a typical current rating of 10 kA (8/20 × 10).

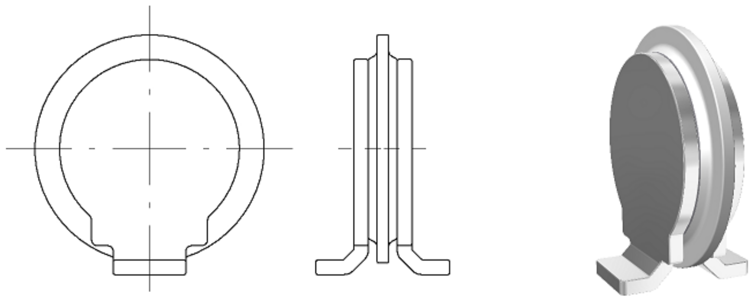

Figure III.4.4 – Two-electrode GDT with reduced axial length for vertical SMT

Dimensions for 2-electrode GDTs, shown in Figure III.4.4, are 2 mm × Ø8 mm with a typical current rating of 10 kA (8/20 × 10).

III.5 Outlines of GDTs with reduced axial length and three-electrodes

Typical outlines of GDTs with reduced axial length, and 3-electrodes for applications with space constrains are shown in Figures III.5.1 through III.5.4.

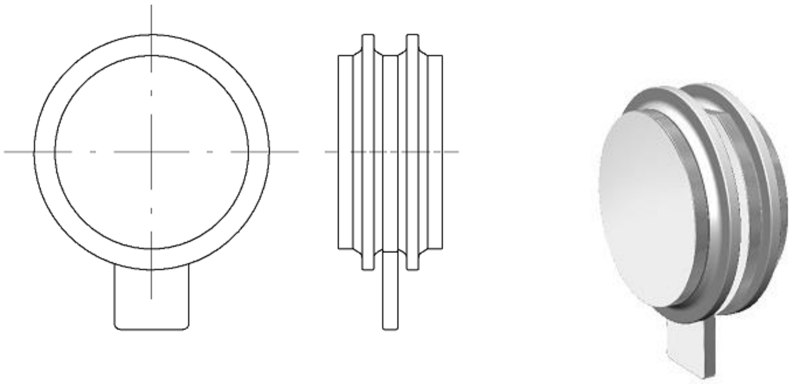

Figure III.5.1 – Three-electrode GDT with reduced axial length for cartridge designs

Dimensions for 3-electrode GDTs, shown in Figure III.5.1, are 3.5 mm × Ø8 mm, with a typical total current rating through centre electrode of 20 kA (8/20 × 10).

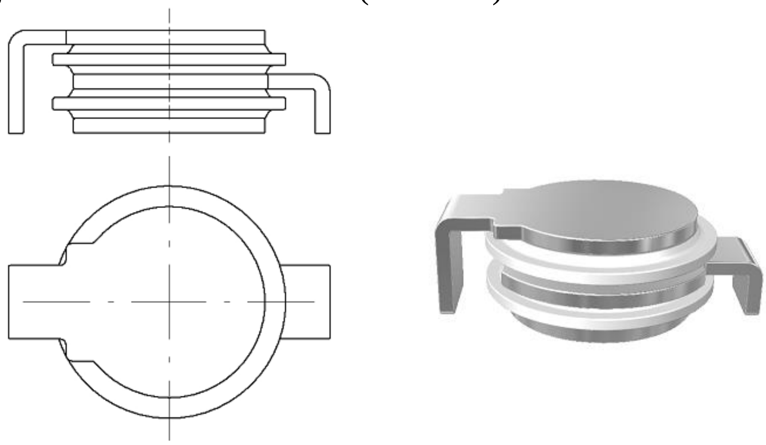

Figure III.5.2 – Three-electrode GDT with reduced axial length for horizontal SMT

Dimensions for 3-electrode GDTs, shown in Figure III.5.2, are 3.5 mm × Ø8 mm, with a typical total current rating through centre electrode of 20 kA (8/20 × 10).

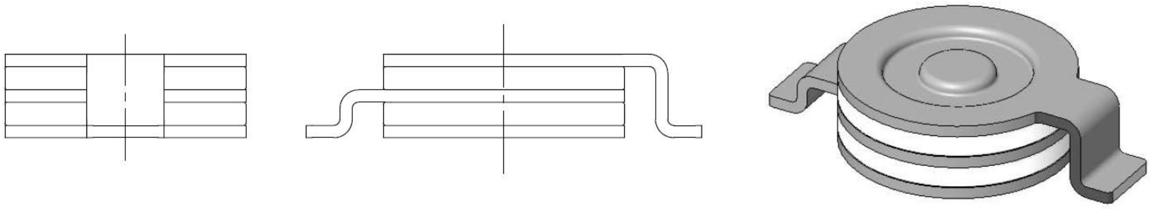

Figure III.5.3 – Three-electrode GDT with reduced axial length for horizontal SMT

Dimensions for 3-electrode GDTs, shown in Figure III.5.3, are 2.7 mm × Ø8 mm, with a typical total current rating through centre electrode of 10 kA (8/20 × 10).

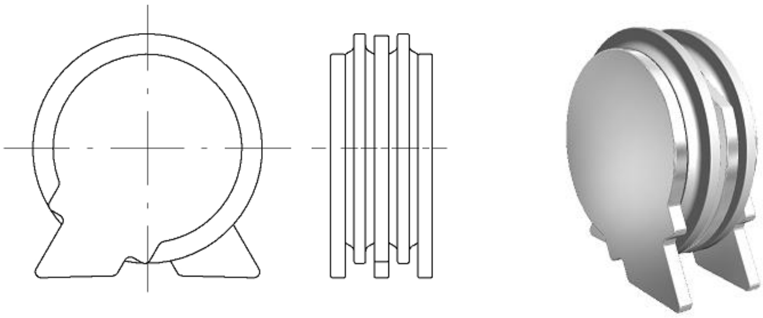

Figure III.5.4 – Three-electrode GDT with reduced axial length for vertical SMT

Dimensions for 3-electrode GDTs, shown in Figure III.5.4, are 3.5 mm × Ø8 mm, with a typical total current rating through centre electrode of 20 kA (8/20 × 10).

III.6 General

For electrical requirements, test methods, storage conditions, environmental tests and informative characteristics refer to [ITU-T K.12].

Some form factor designs are also available with additional external functions such as thermal shorting mechanisms to avoid overheating under long-term a.c. conditions and shunt connected varistors to limit the spark-over voltage for fast rising voltages.

Appendix IV

Three-electrode GDT operation in Ethernet circuits

(This appendix does not form an integral part of this Recommendation.)

IV.1 Introduction

When a 3-electrode GDT has simultaneous surges applied to the outer electrodes, conduction of both halves is expected to occur in fractions of a microsecond. In Ethernet circuits this may not happen and the time for conduction of both halves may take several microseconds. Before simultaneous conduction occurs, a major portion of the surge front is applied differentially to the equipment port. This appendix explains the reasons for this unexpected behaviour.

IV.2 Three-electrode GDT applied to Ethernet twisted pair

IV.2.1 Ethernet port circuit

Figure IV.1 shows a basic schematic of an Ethernet cable connecting equipment Ethernet ports. The main component in the Ethernet port is the magnetics assembly containing an isolating transformer and usually a series common-mode choke. Ports supporting power over Ethernet (PoE) have a primary winding centre-tap to feed or extract the powering current. Each powering mode, A and B, uses two twisted pairs as shown. At surge frequencies, the port impedance for most of the surge is the magnetics assembly winding resistance, which is typically in the region of 1 Ω.

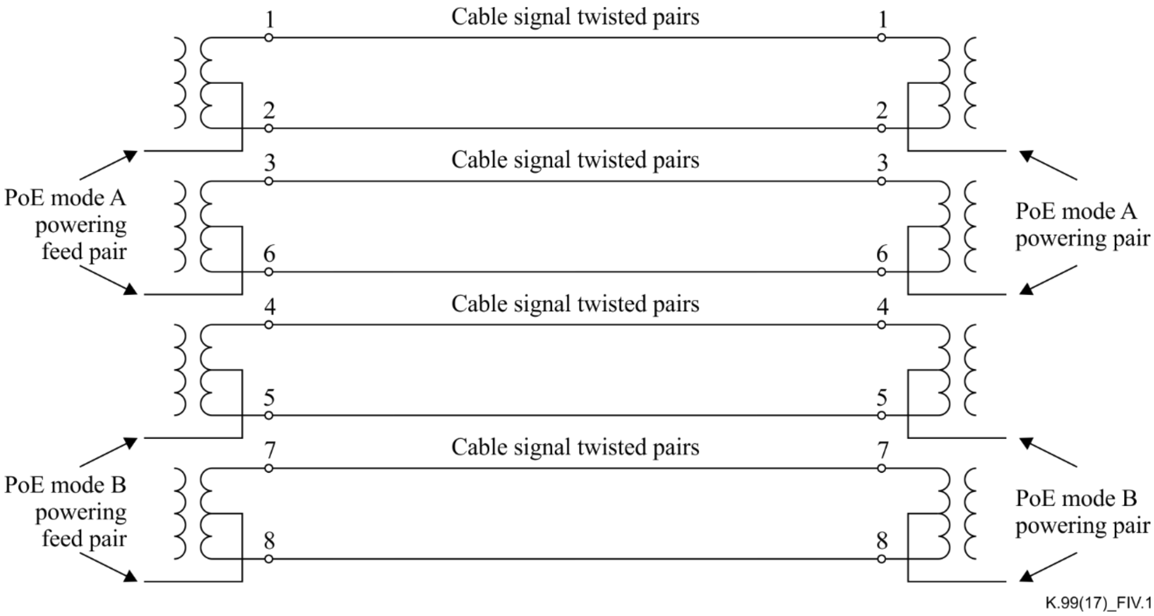

Figure IV.1 – Basic Ethernet cable and equipment ports system

IV.2.2 GDT operation

Figure IV.2 substitutes the port magnetics for a low value resistor, R_{AB}, which effectively shunts the 3-electrode GDT outer A and B connected electrodes together. A common mode surge is applied via two current limiting resistors, R_A and R_B to the port and GDT.

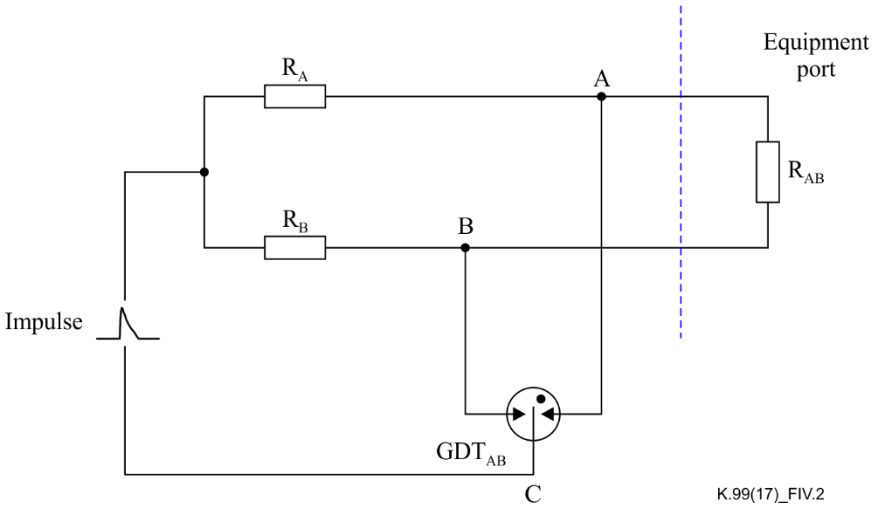

Figure IV.2 – Equivalent circuit under common-mode surge conditions

If the GDT electrode connected to B is the first to spark-over, it draws current, I_B, from the B conductor and current, I_A, from the A conductor via the resistance R_{AB}, see Figure IV.3.

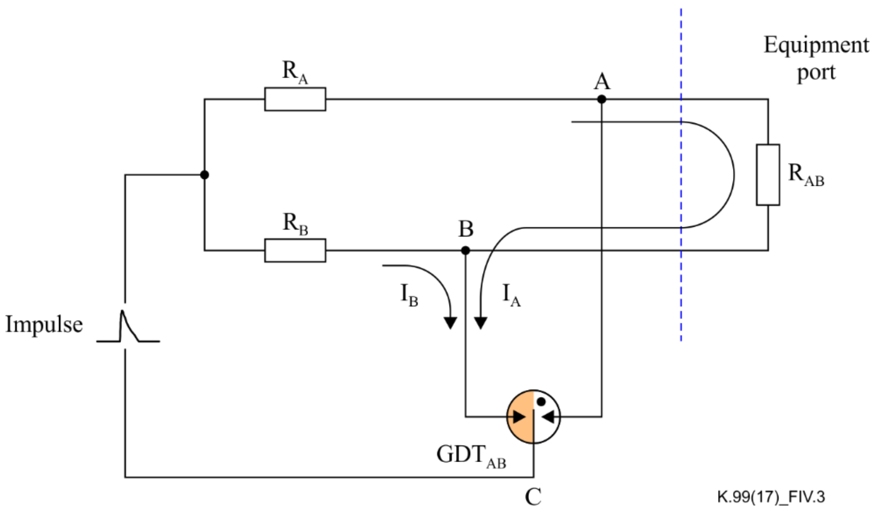

Figure IV.3 – Circuit currents when electrode connected to B is first to spark-over

Under these conditions the voltage on the non-conducting electrode will be V_{ARC} $+I_A x R_{AB}$, where V_{ARC} is the arc voltage of the conducting section. If the current I_A is relatively low, the voltage difference between the outer electrodes will be quite small resulting in a weak electric field in the non-conducting section to attract the plasma from the conducting section. Under such low voltage difference conditions, it may take a period of a few microseconds before the electrode connected to A conducts. During this delay time the port has a differential surge of I_A.

The following clauses show the delay times at increasing levels of surge voltage.

IV.2.3 600 V surge conditions

To ensure the port does not fail the 500 V IEEE 802.3 insulation resistance test the GDT should have a d.c. breakdown above the test level. As a result, with a 600 V surge the GDT does not spark-over, see Figure IV.4.

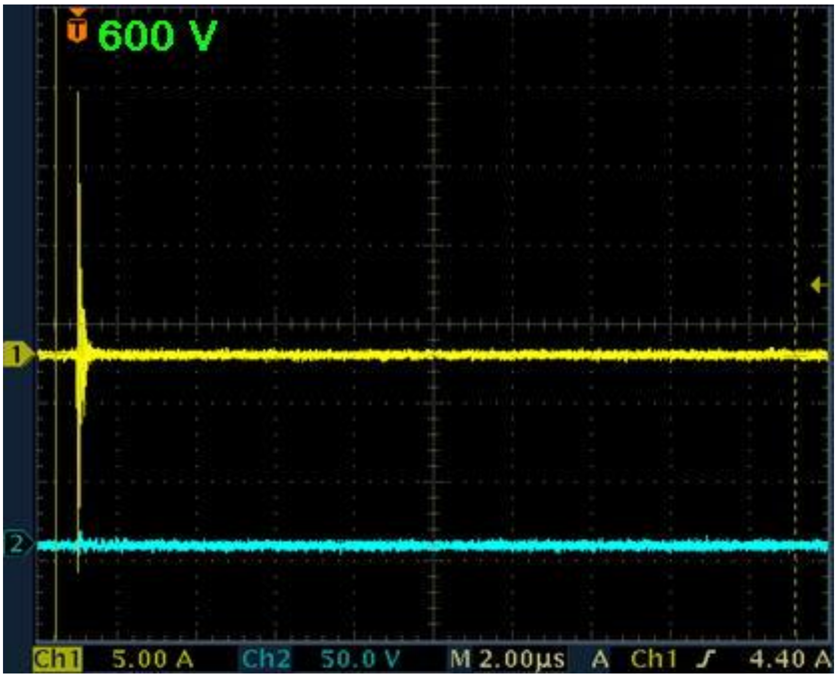

Figure IV.4 – Differential port voltage (cyan line, difference between electrode voltages) and surge current (yellow line) for a 600 V surge

IV.2.4 1.5 kV surge conditions

With a 1.5 kV surge, there is a delay of approximately 2 µs and about 50 V differentially applied to the Ethernet port.

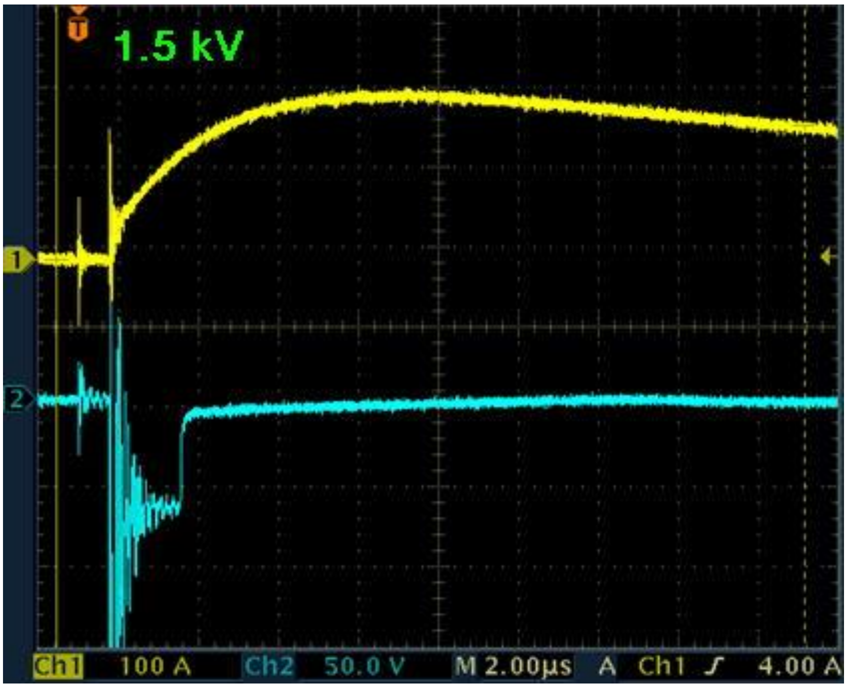

Figure IV.5 – Differential port voltage (cyan line, difference between electrode voltages) and surge current (yellow line) for a 1.5 kV surge

IV.2.5 2.5 kV surge conditions

With a 2.5 kV surge, there is a delay of about 1 µs and 110 V differentially applied to the Ethernet port.

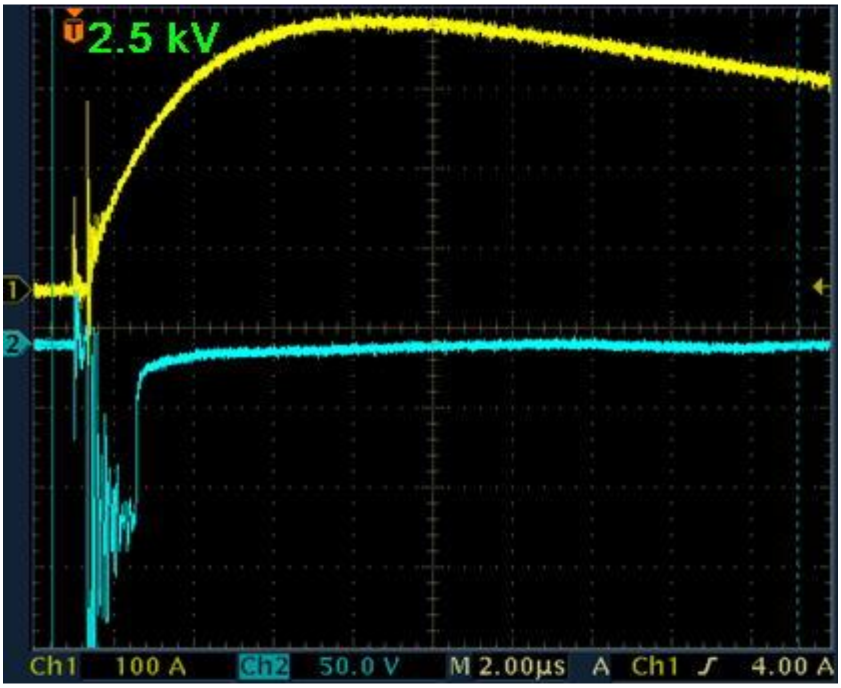

Figure IV.6 – Differential port voltage (cyan line, difference between electrode voltages) and surge current (yellow line) for a 2.5 kV surge

IV.2.6 6 kV surge conditions

With a 6 kV surge, there is almost simultaneous conduction as the port differential voltage produces a strong electric field in the non-conducting section.

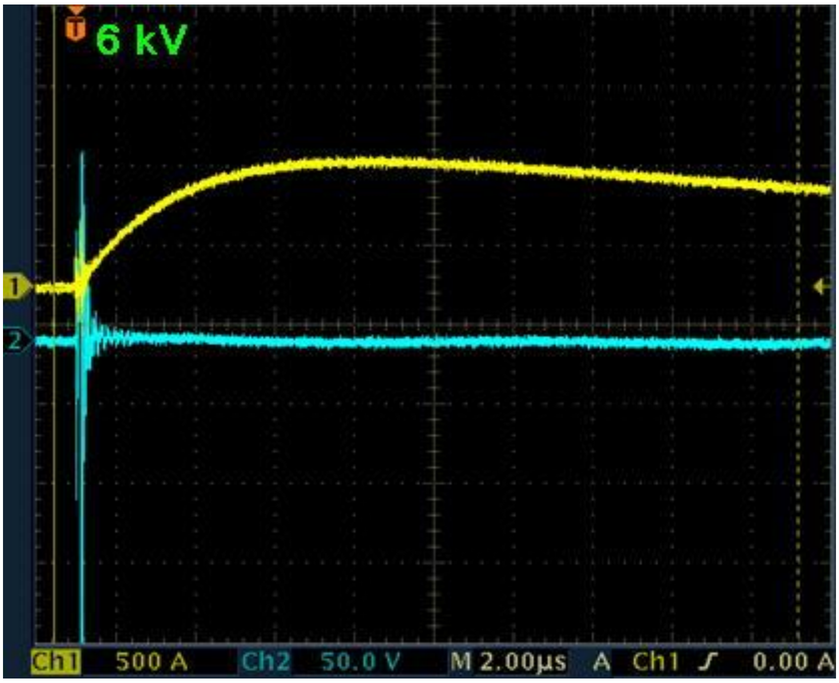

Figure IV.7 – Differential port voltage (cyan line, difference between electrode voltages) and surge current (yellow line) for a 6 kV surge

IV.3 Three-electrode GDT applied to Ethernet powering pair

In this situation, a powering bias exists between the powering pairs. When a surge causes the conduction of the largest voltage section, the powering voltage bias tends to inhibit the conduction of the non-conducting section for times that may exceed those of the twisted pair case.

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