

Application of Gas Discharge Tubes in Power Circuits

The paper gives a brief introduction to the characteristics and principles of gas discharge tubes. Besides, it illustrates failures or burnouts of gas discharge tubes applied in power circuits through actual feedback cases. The main reason is that some characteristics of gas discharge tubes are easy to be neglected at the beginning of the design; the paper also analyzes the important role of gas discharge tubes in the protection of power circuits, as well as the selection of the insulation resistance, the voltage in voltage withstand test and the voltage of gas discharge tubes.

1. Protection Principles of GDT



Gas discharge tubes (GDT), commonly known as lightning protection tubes, are packaged in ceramics hermetically with inert gases inside. When an abnormal over voltage occurs at both ends of the discharge tube, the inert gases inside will break down. At this time, a low resistance channel is formed between two electrodes of the discharge tube, which is similar to the instantaneous close of switches in parallel, discharging the surge current and protecting the electronic circuit at the back end.

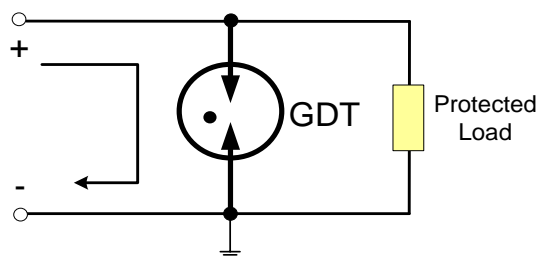


Figure 1. Discharge Path Diagram

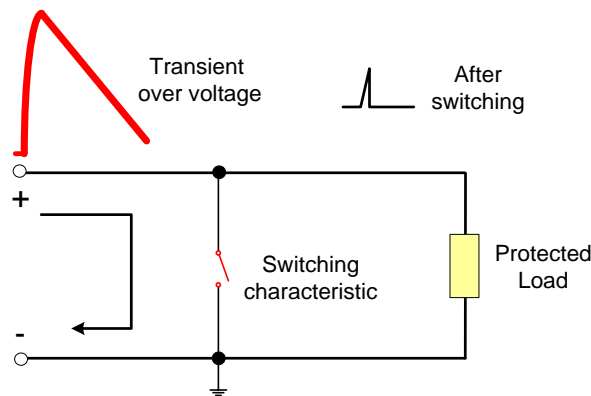


Figure 2. Principle of Equivalence

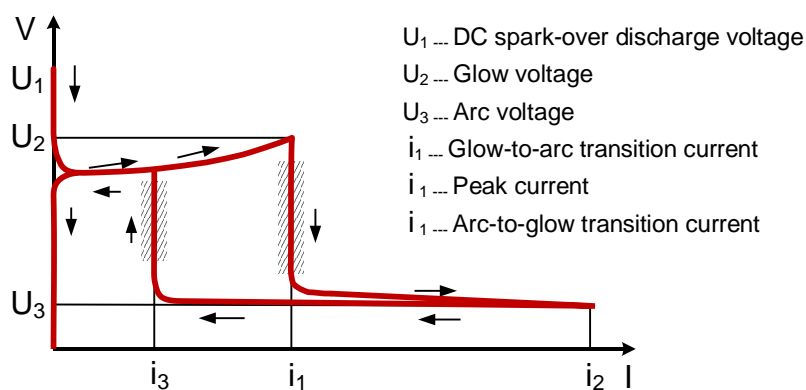


Figure 3. GDT's Volt-Ampere Characteristic Curve

2. Main Parameters of GDT

Part Number	DC Spark-over Voltage	Maximum Impulse Spark-over Voltage	Nominal Impulse Discharge Current	Alternating Discharge Current	Impulse Life	Minimum Insulation Resistance		Maximum Capacitance	Device Marking Code
	100V/s	1000V/ μ s	8/20 μ s, 10 times	50Hz, 1 sec.	10/1000 μ s 100A	Test Voltage	(G Ω)	1MHz	
	(V)	(V)	(kA)	(A)	(times)	DC(V)		(pF)	
2RP600L-8	600 \pm 20%	1300	20	20	500	250	1.0	1.5	2RP600-8

1) DC Spark-over Voltage

The measured voltage should be applied at a rising rate not more than 100 V/s.

2) Maximum Impulse Spark-over Voltage

The maximum impulse spark-over discharge voltage, also known as the pulse

breakdown voltage, refers to the maximum voltage value between both terminals of the impulse voltage applied with the specified rising rate and polarity before the discharge current flows through GDT. Generally, this voltage value is measured when the voltage rising rate is $1000 (1 \pm 10\%) \text{ V}/\mu\text{s}$.

3) Alternating Discharge Current

It is applied with a frequency of 50Hz for 1s.

4) Nominal Impulse Discharge Current

The nominal impulse discharge current is the peak pulse current of a given waveform. Generally, it is an $8/20\mu\text{s}$ pulse current waveform, which can meet 10 impulses.

3. Considerations for GDT's Type Selection

3.1 DC Spark-over Voltage and Impulse Breakdown Voltage

Attention should be paid to the difference between DC spark-over voltage and pulse breakdown voltage during the type selection. The DC spark-over voltage should refer to the working voltage of the circuit, which should be greater than the maximum working voltage of the protected circuit. Otherwise, it will affect the normal operation of the circuit. The pulse breakdown voltage is related to the voltage rising rate of the surge. Figure 4 is the diagram of GDT's on-state voltage at different rising rates. It can be seen from the figure that the higher the rising rate, the higher the breakdown voltage of GDT.

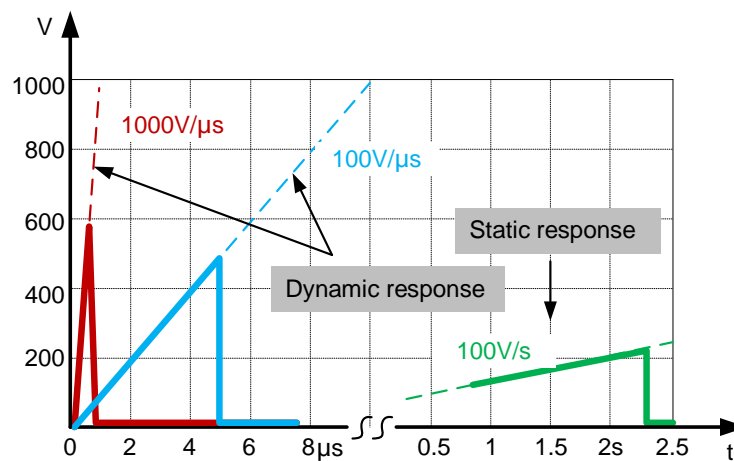


Figure 4. Diagram of GDT's On-state Voltage at Different Rising Rates

3.2 GDT's Follow Current Problem

As shown in Figure 2, GDT is a switching over voltage protection device that has a low on-state voltage and cannot be applied to the protection of power circuits with a high voltage. It is often said that there are follow currents in GDT, which means that if the working voltage of the protected circuit is higher than the on-state voltage of GDT after GDT is turned on, GDT will always be in the on state. If there are heavy currents of the amperage level flowing through the circuit, GDT and the circuit will be damaged.

4. Application of GDT in Power Circuits

4.1 Common Misuses of GDT in Power Circuits

Through investigations and feedback of customers in recent years, it has been found that some engineers have some misunderstandings about discharge tubes, especially about applications of discharge tubes in power interfaces. The paper studies and analyzes this issue through several typical cases:

1) In 2009, an engineer engaged in the development of instrument products in Beijing reported that many burnt-out devices had been returned from the site within three months since their instruments were installed. The ratio was close to 10%. The burnt-out circuit was from the AC220V connector to the discharge tube. Most of the PCB copper foil in this part was burnt or broken, making the product unable to work. Part of the burned circuit is shown in Figure 3.

2) In August 2010, an engineer reported that the DC48 power supply circuit of an industrial switch they produced was seriously burned out. The burnt-out circuit was from the power connector to the discharge tube. The unqualified ratio returned from the site in about half a year was about 5%.



Figure 5. Burnt Circuit Board

Similar cases have occurred repeatedly in recent years and the damage rate is often several times or even tens of times higher than the normal repair rate. Therefore, the quality accidents of these products have caused great economic losses to the enterprises, which also have had serious negative impacts on the brand images of the enterprises.

Through the analysis of the power circuit of the damaged product, it is found that there is one thing in common: the GDT used is directly connected across both ends of the power circuit, as shown in the following figure. (In Figure 6(b), if the zero line and the live line are connected in reverse, the GDT is equivalent to the live line). This design obviously ignores the follow current of the discharge tube, that is, when the discharge tube is activated (the switch is closed), the holding voltage of the follow current may be as low as 10-30V. The voltages of the power supply (220V and 48V) in the two examples above both meet this condition, so the discharge tube may remain the short-circuited state even after the over voltage disappears. It is known to all that the current is usually very large when the circuit is shorted. At this time, the fuse is usually burned. If there is no fuse or the current of the fuse used is too large, the printed board may be burned out first. In conclusion, if this happens, the product will certainly have no way to continue working and needs to be repaired or replaced.

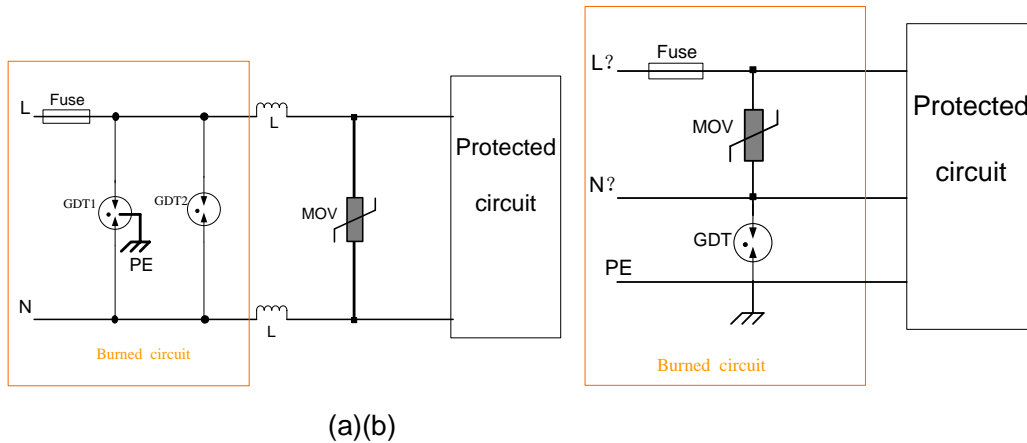


Figure 6. Burnt AC Power Inlet Circuit

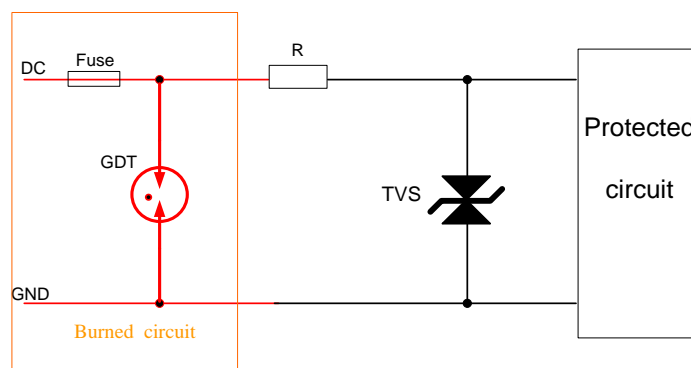


Figure 7. Burnt DC Power Inlet Circuit

4.2 Correct Applications of GDT in Power Circuits

In order to solve the follow current problem of GDT, it is necessary to connect GDT with another protection device (varistor, transient suppression diode, etc.) in series in the circuit. This device should be able to turn off automatically when the over voltage disappears, so that the follow current problem of the discharge tube can be solved. At the same time, because GDT has an insulation resistance of $1G\Omega$ or even more than $10G\Omega$, it can eliminate the leakage current of L/N to the ground and improve the safety and reliability of the electronic product, as shown below:

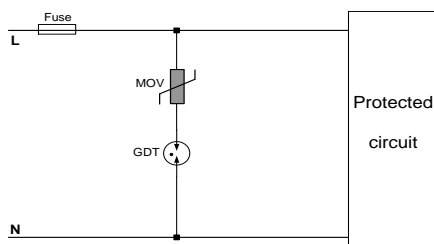


Figure 8. GDT in an Ungrounded Power Supply.

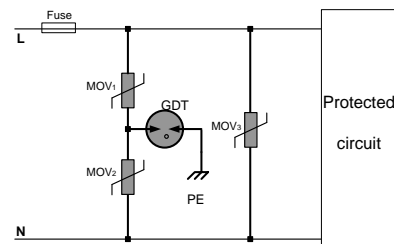


Figure 9. GDT in a Grounded Power Supply.

4.3 Influences of Safety Certification on GDT's Type Selection in Power Systems

It is known that the lower the on-state voltage of the surge protection circuit, the faster it will operate. For example, the voltage of GDT in Figure 8 is 470V or 600V, but many electronic products are required to perform insulation resistance and withstand voltage tests when they apply for relevant certifications. This is the most common safety test project, in which a high voltage is required to be applied between the power cable and the metal casing for a short period of time. The high voltage is usually several times the working voltage, which is generally required to be 1500VAC. It is required that the leakage current shouldn't exceed a certain specification. (generally $\leq 5\text{mA} \sim 20\text{mA}$).

In the voltage withstand test applied with AC1500V (the peak voltage exceeds 2kV), as MOV and GDT have been already turned on, the current passed will far exceed the standard of 5mA, the experiment will not succeed. We have received many similar case consultations. For this circuit, we usually recommend that only adjust the breakdown voltage of GDT to 2500V or more instead of changing the package, thus achieving the performance requirements of the surge and the withstand voltage test.

5. Conclusion

GDT has the characteristics of strong surge discharge capability, high insulation resistance and low junction capacitance. It has been widely used in electronic products. The correct application of GDT can improve the safety and working life of electronic products. However, if it is not applied properly, it will not only be unable to protect the electronic products, but also may cause some unexpected problems. Therefore, a full understanding is the necessary condition to improve the reliability of products at the beginning of design.