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Over Voltage Transient Protection Network Design

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Abstract

Transient over-voltage caused by lighting, switching large inductive loads, couples on to data communication or instrumentation signal lines and introduce series fault alarm conditions and damage instrumentation electronics.

Most of the semi-conductor devices and other sensitive electronic equipment are easily damaged with transients of high amplitude with fast rise time, with threshold energy levels in the range of micro joules to mill joules. Hence, it is very essential to protect the system by hardening the input power supply lines, input/output data and communication lines utilizing various transient suppression techniques to make the system immune to transients. If an electronic system designer intend to build a protection circuit a custom design will be desirable, as the interface or inter-connection could be more effective for the intended environment.

Keywords: Transient over voltage, protection, suppression, let through voltage.

تصميم دائرة حماية من الجهد العابر المتجاوز

الخلاصة:

إن الجهود العابرة التي يسببها البرق أو غلق أو فتح الأحمال ذات المحاثات العالية هـي مصدر تأثير كبير على أنظمة الاتصالات ، وإشارات التقييس ، وخطوط نقل المعلومات ويتسبب أحياناً في تلف المنظومات الإلكترونية الخاصة بالتقييس.

إن معظم الأجهزة الإلكترونية تكون حساسة وقابلة الى العطب بسبب الجهـود العـابرة ذات المستوى العالي وزمن النهوض السريع وكذلك مـستوى طاقـة عتبـة مرتفـع وبحـدود مايكروجول وأحياناً تصل إلى ملي جول. إذن من الأساسي جداً حماية أية منظومة إلكترونية عن طريق حماية مصدر التغذية الخاص بها أو حماية خطوط نقل المعلومات أو خطوط الاتـصالات باستخدام الأنواع المختلفة من مصدات الجهود العابرة لجعل المنظومة محـصنة بـشكل فعـال ومؤثر. وعادة يعمل مصمموا الأنظمة الإلكترونية على بناء دوائر حماية بشكل تقليـدي ، وهـو المفضل ، مع ملاحظة كل تصميم بحيث أنه يتناسب مع ظروف عمل المنظومة والبيئة الخاصـة لتشغيلها.

Keywords: GDT (Gas discharge) , MOV (Metal oxide Varistor), V_f (Firing voltage), V_g (Glowing voltage)

1. Introduction

Majority of electronic system, which are powered by main A.C power or linked with long voltage transmission lines, are prone to disturbances due to over-voltage transients. Some radio systems operating with antenna system installed in tall masts are also reported to have been disturbed due to over-voltage transients generated due to lightning [1]. A review of the protection circuits used to minimize the damage due to over-voltage transients and their design technique is discussed.

2. Sources of over-voltage transients:

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(a) Cloud to ground lighting flash with peak return stroke current I, with variable value 20KA to 200KA.
(b) Switching of reactive loads produces transients voltage up to 10KV normally on power lines (6KV is typical), [2 , 3].
(c) Electrostatic discharge. A person can be charged typically between 0.5 and 15KV depending upon various conditions and the discharge peak current can be up to 70A (Typically 30A).
(d) High power microwave burst can deliver more current energy than lightning.
(e) Over-voltage produced by fuses opening in a transmission lines. The over-voltage transient has been reported to have amplitude 10 times higher than the normal operating voltage and duration of 150μs.
(f) Relays.
(g) Inductive switching transients.
(h) Switching mode power supplies.
(i) Solenoids
(j) High current motors.
(k) High speed logic circuits.

The voltage generated by an inductance ; defined by:

$$V = L \frac{di}{dt} \quad \text{……….} (1)$$

V = peak voltage across the inductor
L = lead inductance
$\frac{di}{dt}$ = time rate change of current

3. Protection network:

One major method of transient over-voltage protection that behaves like a short circuit during over-voltage transients (ex gas discharge tube, spark gapes, metal oxide varistors), [4].

Line protection units are normally constructed with more than one protection device in a network. Here we designed three stages of protection device and protection circuit consisted from GDT, MOV, Tranzorb (TVP) and suitable impedances as shown in fig.(1) ..

The normal let-thro voltage of GDT , MOV, and trazorbs will be selected based on the continuous operating voltage for the instrumentation. However this voltage rating will be gradually increase from tranzorbs to (GDT). The clamping voltage of the tranzorb will be approximately equal to the continuous operating voltage and its tolerance, [5 , 6].

The TVP will react first to the transient over voltage an its response is faster than the other protection devices. Once its starts conducting the current drawn thro Z_2 will increase, such that at an appropriate time the voltage across MOV will be sufficient enough to make MOV to conduct and start drawing current. This will reduce the dissipation by TVP and protect it from damage. Similarly the current thro Z_1 will develop a voltage drop across Z_1 and if the voltage across GDT reaches its break over point, GDT will start conducting and taking the major part of the current induced by transient over voltage. The selection of Z_1 and Z_2 are very important for the network to function as designed.

Let us take that the clamping voltage of TVP is V_z, and that of MOV is V_m and the glowing voltage of GDT as V_g and its firing voltage is V_f [7].

Let the current thro TVP is I_z and thro MOV is I_m

$I_{z\,(max)} R_2 > V_{m\,(max)}$

$$R_2 > \frac{V_{m(\max)}}{I_{z(\max)}} \quad \ldots\ldots (2)$$

in order to ensure that TVP fires first, MOV fires next and then GDT we have to decide the values of Z_1 and Z_2 as given in figure (1):

$I_{m\,(max)} R_1 > V_{f\,(max)}$

$$R_1 > \frac{V_{f(\max)}}{I_{m(\max)}} \quad \ldots\ldots (3)$$

if $V_g > V_z$, V_m then TVP and MOV will be 'ON' for the duration of pulse. But to protects them against burn out we have to ensure.

$$R_2' > \frac{V_g - V_z}{I_{z(\max)}} \quad \ldots\ldots (4)$$

$$R_1' > \frac{V_g - V_m}{I_{z(\max)}} \quad \ldots\ldots (5)$$

5. Design examples:

To apply the design procedure mentioned, three protection networks are considered. Two of them for protection instrumentation and control equipments working on 12VDC and 24VDC supply and the other for 220VAC, 50Hz line voltage operating devices.

4. Design Procedure:

a. Instrumentation and control protection units:

1. 12 VDC Supply:

The devices used are the Tranzorb (1.5KE18A) and MOV (VZ20D220KBS) and GDT (WPGT-2R90) with the following specifications, [6 , 8] :

Tranzorb:

Vz_{max} = 18.9 V
$Vz_{nominal}$ = 18 V
Iz_{max} = 59.5 A

Varistor (MOV):

Vm_{max} = 24 V
$Vm_{nominal}$ = 22 V
Im_{max} = 2000 A

GDT:

V_f = 600 for 1 kV/µs pulse
V_g = 52 V

From equation (2) to (3):

$$R_1 > \frac{V_{f(\max)}}{I_{m(\max)}} = \frac{600}{2000} = 0.3\Omega$$

$$R_2 > \frac{V_{m(\max)}}{I_{z(\max)}} = \frac{24}{59.5} = 0.4\Omega$$

Similarly we can find:

$$R_1' > \frac{V_g - V_m}{I_{z(\max)}} = \frac{52-24}{59.5} = 0.47\Omega$$

$$R_2' > \frac{V_g - V_z}{I_{z(\max)}} = \frac{52-18.9}{59.5} = 0.55\Omega$$

2. for 24 VDC Supply:

The devices are Tranzorb (1.5KE33A), MOV (VZ20D390KBS), GDT (WPGT-2R90) with the following specifications:

Tranzorb:
Vz_{max} = 34.7 V
$Vz_{nominal}$ = 33 V
Iz_{max} = 33 A

Varistor (MOV):
Vm_{max} = 43 V
$Vm_{nominal}$ = 39 V
Im_{max} = 2000 A

GDT:
V_f = 600 for 1 kV/μs pulse
V_g = 52 V

$$R_1 > \frac{V_{f(\max)}}{I_{m(\max)}} = \frac{600}{2000} = 0.3\Omega$$

$$R_2 > \frac{V_{m(\max)}}{I_{z(\max)}} = \frac{43}{33} = 1.3\Omega$$

$$R_1' > \frac{V_g - V_m}{I_{z(\max)}} = \frac{52-43}{33} = 0.27\Omega$$

$$R_2' > \frac{V_g - V_z}{I_{z(\max)}} = \frac{52-34.3}{33} = 0.52\Omega$$

b. In line protection network for 220VAC:

The devices are a bidirectional Tranzorb (1.5KE300AC) and MOV (VZ20D331KBS) and GDT (WPGT-2R600S) with the following specifications:

Tranzorb:
Vz_{max} = 315 V
$Vz_{nominal}$ = 300 V
Iz_{max} = 5 A

Varistor (MOV):
Vm_{max} = 363 V
$Vm_{nominal}$ = 330 V
Im_{max} = 10000 A

GDT:
V_f = 1400 for 1 kV/μs pulse
V_g = 150 V

$$R_1 > \frac{V_{f(\max)}}{I_{m(\max)}} = \frac{1400}{10000} = 0.14\Omega$$

$$R_2 > \frac{V_{m(\max)}}{I_{z(\max)}} = \frac{363}{5} = 72.6\Omega$$

Because R_2 is too high, it is substituted by a turn on snubber inductance with a value of 2mH to limit the di/dt of 0.17A/μs (with 330 V, V_m voltage) well below the 0.5 A/μs, which it is the Tranzorb limit [9] .

In practice we have to use higher value resistors of suitable power rating and preferably wire wound to take advantage of the inductance effect.

Research experimental results and evaluation:

Fig.(2) shows the circuit to test the protection networks in order to get the value of the voltage going to the designed load [10] .

The network is in parallel with the system. The experiment was done by shooting surge power with 6000V level at 1.2/50μs as shown in Fig.(3). Table (1) shows the surge voltages and current deemed to represent the indoor environment and recommended for use in design protection systems [11-13].

Tables (2-4) indicates that the test performed has a satisfactory results and the design was implemented with suitable values for the protection networks.

7. Conclusions

High frequency lighting and switching transients are often very disruptive to sensitive electronic circuits, and the characteristics of these transients can seldom be predicated for the system operating environment. Elimination of these undesirable and unpredictable signals is usually accomplished during the design and development stage, by incorporating appropriate protection devices at the entry point of these transients, so that the system is immure to any type of transients generated from internal or external sources, if proper protection is not provided at the time of EMI/EMC performance evaluation, the system may fail to meet the transient requirement and providing protection devices at this stage may be very difficult, hence it is emphasized that all critical / sensitive electronic network essentially EMI hardened by incorporation combined protection circuitry on power supply input, data input/output and communication lines.

References

[1] Clayton R., Paul "Introduction to electromagnetic compatibility", 2nd edition, John Wiley. 2006.

[2] Standler, R.B. "Protection of Electronic Circuits from over-voltages", John Wiley and sons, 1989.

[3] John R. Barnes, "Electronic System Design Interference and Noise Control Techniques". 1987 by prentice-Hall Inc. Englewood cliffs, New Jersey 07632.

[4]Williams, Tim. "EMC for product designers", 3rd edition, Newnes, 2001.

[5] Melvill Clark, O. "Transient Voltage Suppressors". General Semi Conductor Industries, INC, USA.

[6]M. O. Durham, K. D. Durham "TVSS designs", IEEE Industry Applications Magazine, Vol.8, No.5, Sep. Oct. 2002, pp31-36.

[7]Korn S. R. "Transient Voltage Suppression Manual" General Electric Co. 1983.

[8]World products Inc. protection products catalog, available at www.worldproduct.com. Rev.2.4 (04.16.2008)

[9] Tenca, P.; Lipo., T.A. "A decentralized protection scheme for converters utilizing a DC-link inductor. "Industrial Electronics Society", IECON 2005. 32nd Annual conference of IEEE. November 6-10, 2005; pp.854-859 (to appear in IEEE transactions on Industrial Electronics).

[10] Proceedings of world academy of science, Engineering and technology volume 28 July 2007, ISSN 1307-6884.

[11]IEEE. Std. C62.45: 2002, IEEE recommended practice on surge testing for equipment connected to low-voltage (1000 or less) AC power circuits.

[12] IEEE. Std. C62.41.1: 2002 Guide on the surge environment in low voltage (1000 or less) AC power circuits.

[13]IEC 6100-4-5, Electromagnetic compatibility (EMC), part 4-5, Testing and measurement techniques, surge immunity test, 2000.

Table(1) Surge voltages & currents representing the indoor Environment [12]

LOCATION CATEGORY CENTER	COMPARABLE TO IEC 664 CATEGORY	IMPULSE		TYPE OF SPECIMEN OR LOAD CIRCUIT CIRCUIT	ENERGY (JOULES) DEPOSITED IN A SUPPRESSOR WITH CLAMPING VOLTAGE	
		WAVEFORM	MEDIUM EXPOSURE AMPLITUDE		500V	1000V
					(120V Sys.)	(240V Sys.)
A. Long branch circuits and outlets	II	0.5μs - 100kHz	6kV	High Impedance (Note 1)	-	-
			200A	Low Impedance (Note 2)	0.8	1.6
B. Major feeders short branch circuits, and load center	III	1.2/50μs	6kV	High Impedance (Note 1)		
		8/20μs	3kA	Low Impedance (Note 2)	40	80
		0.5μs - 100kHz	6kV	High Impedance (Note 1)	-	-
			500A	Low Impedance	2	4

NOTES

1. For high-impedance test specimens or load circuits, the voltage shown represents the surge voltage. In making simulation tests, use that value for the open-circuit voltage of the test generator.
2. For low-impedance test specimens or load circuits, the current shown represents the discharge current of the surge (not the short-circuit current of the power system). In making simulation tests, use that current for the short circuit current of the test generator.
3. Other suppressors which have different clamping voltages would receive different energy levels.

Table (2) Test results for 12 VDC protection network

Maximum supply voltage 14 VDC
Nominal clamping voltage 18 V
Specified let through voltage 26 V

Sequence Test	Voltage Test V_T(V)	Measured Clamping Voltage Vc(V)
1	6000	18.18
2	6000	18.30
3	6000	18.32
4	6000	18.33
5	6000	18.37

Table (3) Test results for 24 VDC protection network

Maximum supply voltage 28.2 VDC
Nominal clamping voltage 33 V
Specified let through voltage 45.7 V

Sequence Test	Voltage Test V_T(V)	Measured Clamping Voltage Vc(V)
1	6000	33.4
2	6000	33.6
3	6000	33.7
4	6000	33.7
5	6000	33.9

Table 4: Test results for 220 VAC protection network

Maximum supply voltage 256 VAC
Nominal clamping voltage 300 V
Specified let through voltage 414 V

Sequence Test	Voltage Test VT(V)	Measured Clamping Voltage Vc(V)
1	6000	300.6
2	6000	300.9
3	6000	301.2
4	6000	301.3
5	6000	301.4

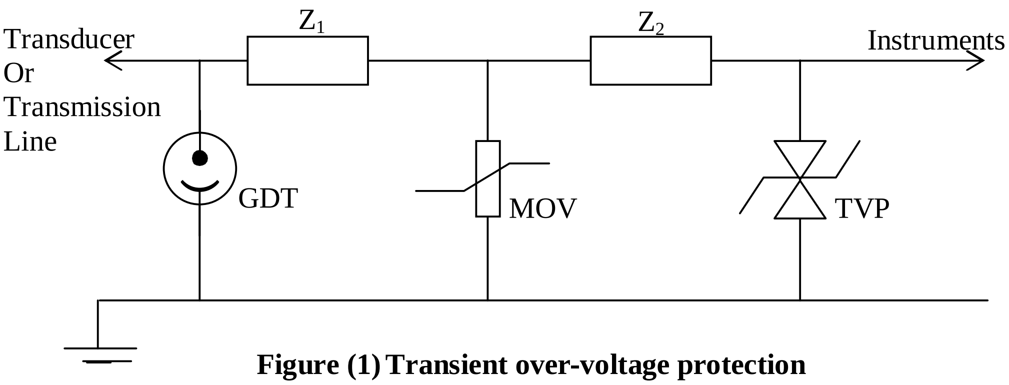

Figure (1) Transient over-voltage protection network

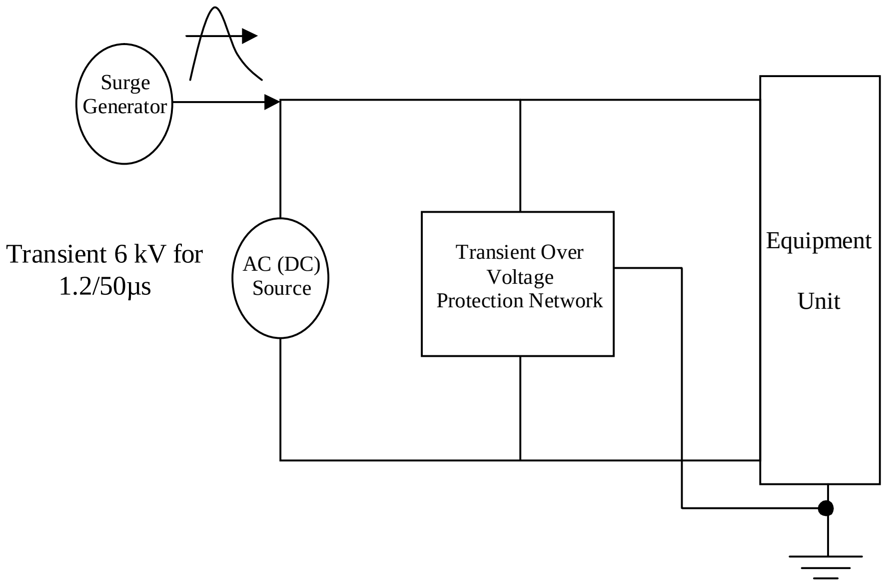

Figure (2) Circuit to test the device for transient over voltage

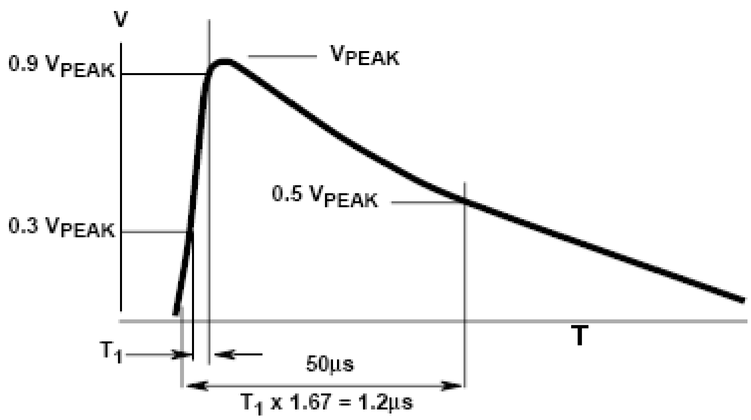

Figure (3) Waveform of standard voltage surge at 1.2/50µs