



IEC 62368-1 and Pluggable Mains Powered Equipment Surge Protection

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IEC 62368-1 — Scope

- IEC 62368-1 Ed.3, Audio/video, information and communication technology equipment - Part 1: Safety requirements hazard-based standard was published 2018-10-04.
- The standard covers the safety of electrical and electronic equipment within the field of audio, video, information and communication technology, and business and office machines with a rated voltage not exceeding 600 V. The standard does not include requirements for performance or functional characteristics of equipment.


IEC 62368-1 — Components and remarks

- IEC 62368-1 is also applicable to components and subassemblies intended for incorporation in the equipment. Such components and subassemblies need not comply with every requirement of IEC 62368-1, provided that the complete equipment, incorporating such components and subassemblies, does comply.
- The standard is nearly 400 pages long, often building a given safety requirement from multiple clauses or referenced standards.
- The PEG 2016 “Bilingual Safety Language in ITU-T Recommendations” presentation gave a comparison of associated IEC 60950-1 and IEC 62368-1 terms and definitions.
<https://www.pegconference.com/wp-content/uploads/2018/08/bilingualsafety-mmaytum.pdf>



IEC 62368-1 — Normative references

- The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. **For dated references, only the edition cited applies.** For undated references, the latest edition of the referenced document (including any amendments) applies.
- IEC 61051-1, Varistors for use in electronic equipment – Part 1: Generic specification (latest edition 2018-10-29)
- IEC 61051-2:**1991**/AMD1:**2009**, Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors
- IEC 61643-11:**2011**, Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods
- IEC 61643-331:**2017**, Components for low-voltage surge protective devices – Part 331: Performance requirements and test methods for metal oxide varistors (MOV)



IEC TC 108 (IEC 62368-1) terminology

- Although IEC TC 108 is formed from 29 countries and their experts, clearly an appropriate knowledge of established IEC surge protective terms and definitions is missing.
- Established IEC item terms are:
 - **assembly:** any composite item which is intended to be repaired
NOTE—See IEC 61163-1, ed. 2.0 (2006-06)
 - **circuit:** interconnection of electrical components
NOTE—See ISO/IEC 14776-121, ed. 1.0 (2010-10)
 - **component:** any single item which is not intended to be repaired which cannot be physically divided into smaller parts without losing its particular function
NOTE—See IEC 60050-151-11-21 & IEC 61163-1, ed. 2.0 (2006-06)
 - **device:** combination of components having a given function, forming part of a piece of equipment, apparatus, or system
NOTE—See IEC 61000-5-6, ed. 1.0 (2002-06)
 - **item:** part, component, device, functional unit, equipment, subsystem or system that can be individually considered
NOTE—See IEC 60300-3-12, ed. 2.0 (2011-02)



IEC surge protection terminology

- For overvoltage and overcurrent protective item terms, IEC TC 37 and TC 42 are the lead committees. Item terms are:
 - **protective function:** function to implement protective actions
NOTE—See IEC 60050-395-07-87
 - **surge protective component, SPC:** component primarily intended to provide a protective function
NOTE 1—Overvoltage mitigation component examples are GDTs, MOVs, thyristors and PN-junction diodes.
NOTE 2—Overcurrent mitigation component examples are positive temperature coefficient thermistors and 2-terminal electronic current limiters
 - **surge protective device, SPD:** device that restricts the voltage of a designated port or ports, caused by a surge, when it exceeds a predetermined level
NOTE 1—Secondary functions may be incorporated, such as a current-limiting to restrict a terminal current.
NOTE 2—Typically, the protective circuit has at least one non-linear voltage-limiting surge protective component.
NOTE 3—An SPD is a complete assembly, having terminals to connect to the circuit conductors.
NOTE 4—See IEC 61643-21, ed. 1.0, amd. 1 (2008-04)
 - **surge suppressor:** device designed to limit the surge voltage between two parts within the space to be protected, such as spark gap, surge diverter or semiconductor device
NOTE—See IEC 60728-11, ed. 3.0 (2010-06)

IEC 62368-1 examples of misused terminology



Surge protective device
SPD in one form factor



Metal oxide varistor
Type of SPC

- Clause 5.4.11.2: SPDs that bridge the separation between ES1 or ES2 circuitry intended to be connected to.....
Not just SPDs, need all items with an overvoltage protective function. “Overvoltage protection that bridges the separation between ES1 or ES2 circuitry intended to be connected to.....”
- Clause 5.5.7 (SPDs):
Where an SPD is used between the mains and protective earthing,
Not just SPDs again. “Where an overvoltage protection is used between the mains and protective earthing,”
NOTE 1 Some examples of SPDs are MOVs, varistors and GDTs. A varistor is sometimes referred to as a VDR or a metal oxide varistor (MOV).

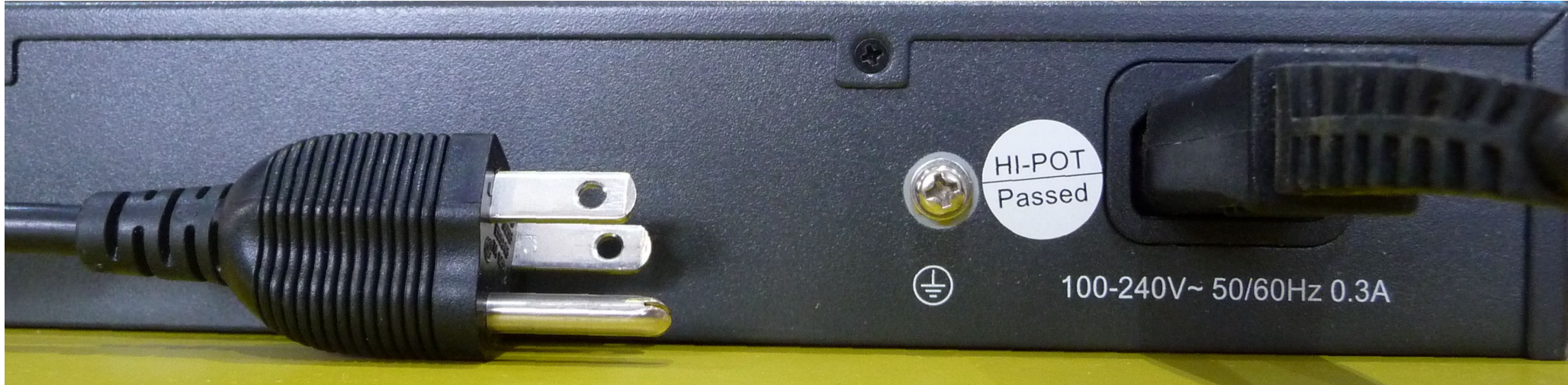
This clearly shows the lack of surge protection terminology understanding in TC 108, the examples are all SPCs not SPDs.



Perceived varistor hazards, tests and safeguards

- Clause G.8.2.1: A varistor shall be regarded as a PIS (potential ignition source).
 - Tests according to G.8.2.2 (overload) and G.8.2.3 (temporary overvoltage) applied as listed in Table G.10.
 - Clause 6.4: is referenced for safeguards against fire under single fault conditions
- Clause 5.5.7: Electric shock hazard resulting from overvoltage protection used between the mains and an unreliable protective earth.
 - Protection shall consist of a varistor and a (safeguard) GDT connected in series

Pluggable equipment type A and unreliable protective earth (PE) condition



- Equipment: AC 100-240 V, Hi-Pot tested and terminal for permanent PE connection.
- 3-pin to 2-pin adaptor (ground lifter) and travel adaptors can break PE continuity



Pluggable equipment type A and series GDT requirements for supply to unreliable earth overvoltage protection

- **pluggable equipment type A:** equipment that is intended for connection to the mains via a non-industrial plug and socket-outlet or via a non-industrial appliance coupler, or both
- Clause 5.5.7: GDT shall comply with:
 - electric strength test of 5.4.9.1 for basic insulation;
 - external clearance distance requirements of 5.4.2; and
 - external creepage distance requirements of 5.4.3



5.4.9.1 Test procedure for type testing of solid insulation - 1

- Prerequisite information on AC mains overvoltage category
 - **overvoltage category:** numeral defining a transient overvoltage condition
See IEC 60664-2-1, ed. 2.0 (2011-01)
 - Clause 5.4.2.3.2.2: In general, clearances in equipment intended to be connected to the AC mains, shall be designed for overvoltage category II.
 - Table I.1 – Overvoltage categories: Overvoltage category II applies to pluggable or permanently connected equipment that will be supplied from the building wiring such as household appliances, portable tools, home electronics and most ITE used in the building.
 - In general IEC 62368-1 seems to favour overvoltage category II

5.4.9.1 Test procedure for type testing of solid insulation - 2

- Table 12 gives overvoltage category voltages

AC mains voltage up to and including	Mains transient voltage V peak Test generator is normally a 1.2/50-8/20			
	Overvoltage Category			
V a.c.	I	II	III	IV
150	800	1500	2500	4000
300	1500	2500	4000	6000

- Overvoltage category II is 1.5 kV for up to 150 V a.c. and 2.5 kV for up to 300 V a.c.

5.4.9.1 Test procedure for type testing of solid insulation - 3

- Highest voltage from Tables 25, 26 and 27 is the insulation test voltage

Required withstand voltage up to and including	Table 25 Test voltage for basic insulation	Peak of the working voltages and recurring peak voltages	Table 26 Test voltage for basic insulation
kV peak	kV peak or DC	kV peak	kV peak or DC
		0.33	0.43
		0.5	0.65
		0.8	1.04
1.5	1.5		
2.5	2.5		
4	4		

Nominal mains system voltage	Table 27 Test voltage for basic insulation
V a.c.	kV peak or DC
Up to and including 250	2
Over 250 up to and including 600	2.5

- For 1.5 kV & up to 150 V a.c.
– test voltage is 2 kV (Table 27)
- For 2.5 kV & up to 300 V a.c.
– test voltage is 2.5 kV (Tables 25 and 27)



5.4.9.1 Test procedure for type testing of solid insulation - 4

- During the AC or DC insulation test:
 - There shall be no insulation breakdown. Insulation breakdown is considered to have occurred when the current that flows as a result of the application of the test voltage, rapidly increases in an uncontrolled manner, that is, the insulation does not restrict the flow of the current. Corona discharge or a single momentary flashover is not regarded as insulation breakdown.
 - For a GDT this means that sparkover or breakdown does not occur.
 - Makes AC or DC breakdown > 2 kV for up to 150 V AC mains and 2.5 kV for up to 300 V AC mains.

5.4.2 clearance distance requirements and 5.4.3 creepage distance requirements

- Clause 5.4.2 Clearances:
 - There are several procedures that can be used for clearance determination. A table for two of the procedures are shown below.

Voltage up to and including	Table 10 Minimum clearances for Basic insulation	Withstand voltage up to and including	Table 14 Minimum clearances for Basic insulation
peak	mm	V peak or DC	mm
1500	0.76	1500	0.5
2000	1.27	2000	1.0
2500	1.8	2500	1.5
3000	2.4	3000	2.0
4000	3.8	4000	3.0

- Clause 5.4.3 Creepage:
 - For glass, mica, glazed ceramic or similar inorganic materials, if the minimum creepage distance is greater than the applicable minimum clearance, the value of minimum clearance may be applied as the minimum creepage distance.

Clause G.8: Varistor or GDT and varistor combination tests and parameters

- A varistor or **GDT and varistor combination** has the following requirements:
 - G.8.1 General – for varistor only. References IEC 61051-2:1991/AMD1:2009 or IEC 61643-331:2017 and IEC 60695-11-5:2016 (Needle-flame test).
 - G.8.2 Safeguards against fire
 - G.8.2.1 General – for varistor (PIS) only. References 6.4.1 (General - safeguards against fire), G.8.2.2 and G.8.2.3 testing.
 - G.8.2.2 Overload test applied to either a varistor or a **surge suppression circuit containing varistors** connected L to L or L to N or L to PE, or N to PE.
 - G.8.2.3 Temporary overvoltage test applied to **surge suppression circuit containing varistors** connected between L to E, or N to E. References IEC 61643-11:2011 (compliance criteria of B.4.8 may be used as an alternative)

G.8.1 General – for varistor only

- Preferred climatic categories

IEC standard	IEC 61051-2	IEC 61643-331
Temperature range	-10 °C to +85 °C	-40 °C to +85 °C
Humidity	damp heat, steady state 21 days (IEC 60068-2-30:2005)	25 % to 75 %

- Maximum continuous voltage
 - >1.25 times the equipment rated voltage; or
 - >1.25 times the equipment voltage range rating upper limit
 - Nominal 230 V AC mains is $\pm 10\%$ making the varistor maximum continuous operating voltage, MCOV, either 288 V a.c. (nominal) or 316 V a.c. (upper range) depending on equipment voltage marking (IEC 61293:1994, Marking of electrical equipment with ratings related to electrical supply - Safety requirements)

G.8.1 General – for varistor only, continued

- Test with combination wave impulse generator
 - Selected from 2.3.6 in IEC 61051-2/AMD1

Voltage line to neutral derived from nominal voltage a.c. or d.c. up to and including	Combination wave generator 61051-2 Amend. 1 values (based on overvoltage category I, II and III of IEC 60664-1)		
	I	II	III
300 V	1.5 kV / 0.75 kA	2.5 kV / 1.25 kA	4.0 kV / 2.0 kA

- or from 8.1.1 of IEC 61643-331, Figure 4.
 - There isn't a clause 8.1.1 in IEC 61643-331:2017, but there is a Figure 4!
- Table 12 (overvoltage categories) mains voltage is overridden by “Mains under 300 V is considered to be 300 V.”
- IEC 60695-11-5 body needle flame test
 - Duration of test flame: 10 s, after flame time: 5 s
 - Needle flame test not performed if body of surge suppression varistor is V-1 class material.



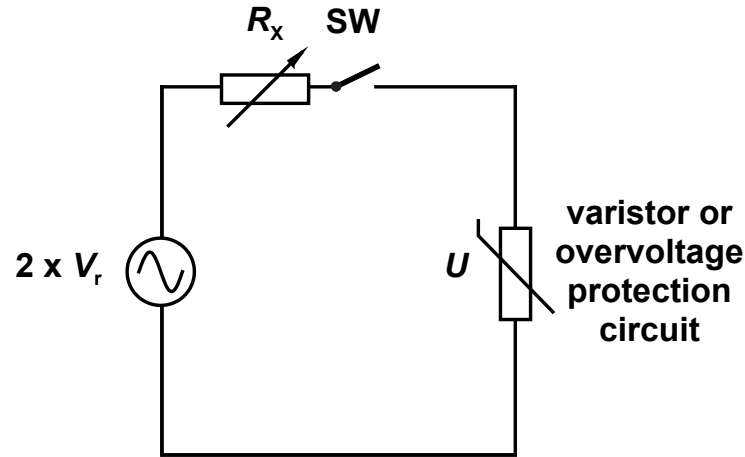
G.8.2 Safeguards against fire

G.8.2.1 General – for varistor only

- G.8.2.1 General – for varistor (PIS) only. References 6.4.1 (General - safeguards against fire), G.8.2.2 and G.8.2.3 testing.

G.8.2 Safeguards against fire

G.8.2.2 Overload test - varistor or a surge protective circuit



It is noted that during the test, the current may:

- Fall to zero due to the operation of a protective component such as a fuse, a thermal fuse; or
 - Conduct current due to the operation of a GDT. (overvoltage protection circuit containing varistors and GDTs)
- Appropriate to L to L or L to N or L to PE, or N to PE protection
 - Applies twice the equipment rated voltage (V_r) or the upper voltage of the rated voltage range (V_r) to the varistor/MOV or an overvoltage protective circuit.
 - Voltage source resistance, R_x , is initially set to limit the prospective current to 0.125 A. Subsequent test runs halve the R_x value and double the prospective current for each new test e.g. 0.25 A, 0.5 A, 1 A, 2 A, 4 A etc.
 - A test is run until the monitored current falls to zero or temperature stability occurs (no current change in probably a 10 min period).
 - Testing is terminated when the first current interruption occurs.
 - Pass criteria are that during and following the test, there shall be no risk of fire and equipment safeguards, other than the varistor under test, shall remain effective.



G.8.2 Safeguards against fire

G.8.2.2 Overload test - observations

- If the purpose of G.8.2.2 is to induce varistor failure through overdissipation, choosing a varistor with a maximum continuous voltage rating of $>2xV_r$ renders the test ineffectual.
 - To cause overdissipation, the source voltage should be based on the varistor rating not the equipment rating. Logically, a source voltage like twice the varistor maximum continuous voltage rating should be used.
- Noted was the circuit current may conduct current due to the operation of a GDT. (overvoltage protection circuit containing a series GDT and varistor elements).
 - With a 5.5.7 compliant GDT this cannot happen as the GDT breakdown voltage is >2 kV and the $2xV_r$ voltage source is not likely to exceed 500 V a.c.
 - Use of a series connected 5.5.7 compliant GDT and varistor renders G.8.2.2 a no test



G.8.2 Safeguards against fire

G.8.2.3 Temporary overvoltage (TOV) tests - surge protective circuit

- Appropriate to an **overvoltage protection circuit containing varistor element** connected between L to E, or N to E.
- Testing details are in:
 - IEC 61643-11:2011: 8.3.8.1 TOVs caused by faults in the low voltage system
 - IEC 61643-11:2011: 8.3.8.2 TOVs caused by faults in the high (medium) voltage system

G.8.2 Safeguards against fire

G.8.2.3 Temporary overvoltage (TOV) tests – test values

- International TOV L-PE and N-PE test values (excludes USA and Japan)
Derived from IEC 61643-11 Tables A.1 and B.1 for single phase 230 V a.c.

AC System	SPDs connected between	Nominal AC voltage V	U_{ref} for TOV test V	LV faults (8.3.8.1)		HV faults (8.3.8.2)
				in consumer installation must withstand test time $t_T = 5$ s	in distribution and N conductor break can fail safely. test time $t_T = 120$ min	can fail safely. test time $t_T = 0.2$ s
TOV test voltage, $U_{(TOV)}$ V						
TN-C	L-PE	230	255	367	442	n/a
	N-PE			n/a	n/a	n/a
TT	L-PE	230	255	442	367	1455
	N-PE			n/a	n/a	1200
IT	L-PE	230	255	n/a	n/a	1455
	N-PE			n/a	n/a	1455
Maximum value	L-PE	230	255	442	442	1455
	N-PE					

For an overview of AC system designations see ITU-T K Suppl. 7 (05/2017): ITU-T K.44 – AC supply configurations

G.8.2 Safeguards against fire

G.8.2.3 Temporary overvoltage (TOV) tests – test values

- Japanese TOV L-PE and N-PE test values

Derived from IEC 61643-11 Tables A.1 and B.3 for single phase 100 V a.c.

System	SPDs connected between	Nominal AC voltage V	U_{ref} for TOV test V	LV faults (8.3.8.1)	HV faults (8.3.8.2)		
				in distribution and N conductor break can fail safely. test time $t_T = 120$ min	can fail safely. test time $t_T = \text{steady state}$	can fail safely. test time $t_T = 2$ s	can fail safely. test time $t_T = 1$ s
				TOV test voltage, $U_{(TOV)}$ V			
TN-C	L-PE	100	110	190	n/a	n/a	n/a
	N-PE			n/a	n/a	n/a	n/a
TT	L-PE	100	110	190	290	410	710
	N-PE			n/a	150	300	600
IT	L-PE	100	110	n/a	n/a	n/a	1310
	N-PE			n/a	n/a	n/a	1310
Maximum value	L-PE	100	110	190	290	410	1310
	N-PE						

G.8.2 Safeguards against fire

G.8.2.3 Temporary overvoltage (TOV) tests – test values

- North American systems TOV L-PE and N-PE test values
Derived from IEC 61643-11:2011 Tables A.1 and B.2 for split phase 120 V a.c.

System	SPDs connected between	Nominal AC voltage V	U_{ref} for TOV test V	LV faults (8.3.8.1)	HV faults (8.3.8.2)
				TOV test voltage, $U_{(TOV)}$ V	
Split phase TN system	L-PE	120 / 240 (L-L)	132 / 264 (L-L)	Values are under consideration	Values are under consideration
	N-PE				

General reading on overvoltages:

TOV effects on surge-protective devices by Dalibor Kladar, François Martzloff, and Doni Nastasi

Transient control levels - A Proposal for Insulation Coordination in Low-Voltage Systems by F.A. Fisher and F. D. Martzloff

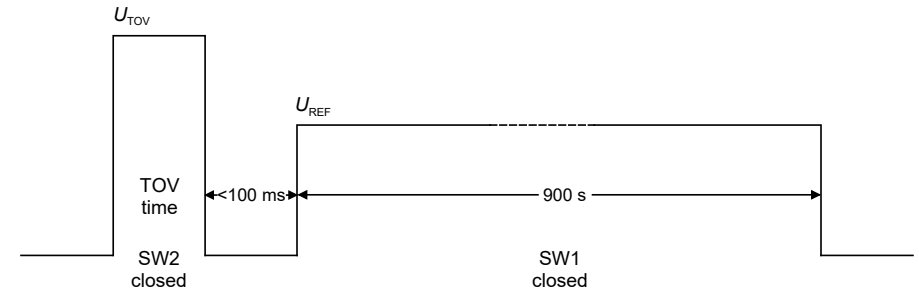
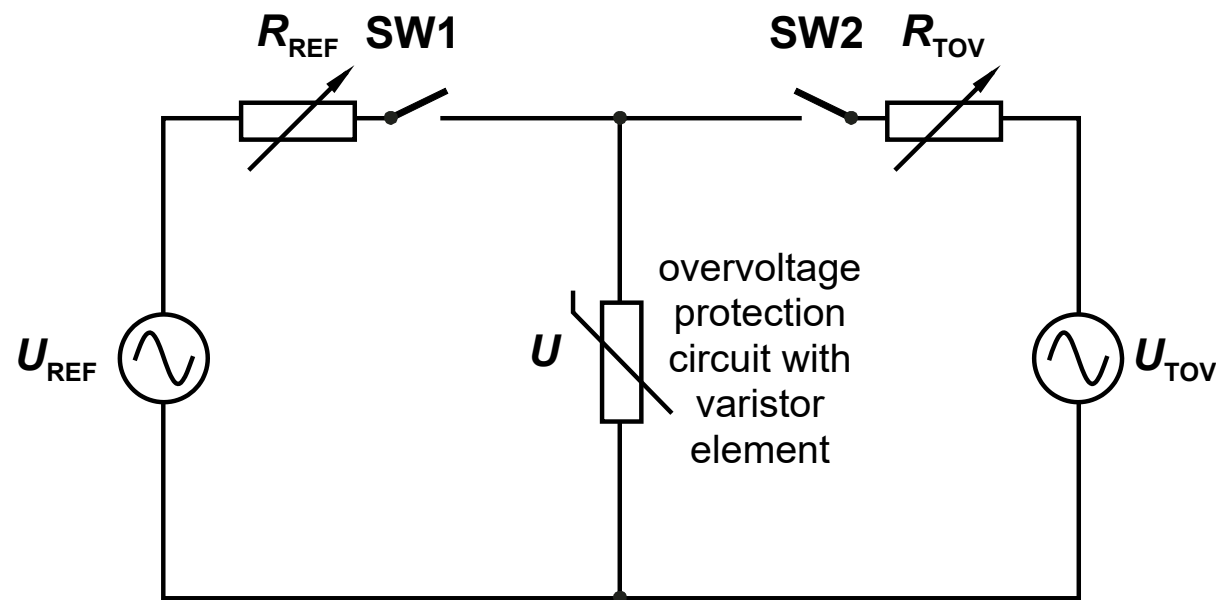
IEC TR 62066:2002, Surge overvoltages and surge protection in low-voltage a.c. power systems - General basic information

ArresterFacts 028 Understanding temporary overvoltage behaviour of arresters Ed 2.0 by Jonathan Woodworth

G.8.2 Safeguards against fire

G.8.2.3, IEC 61643-11 8.3.8.1 low voltage system fault TOVs

- IEC 61643-11:2011: 8.3.8.1 example test circuit

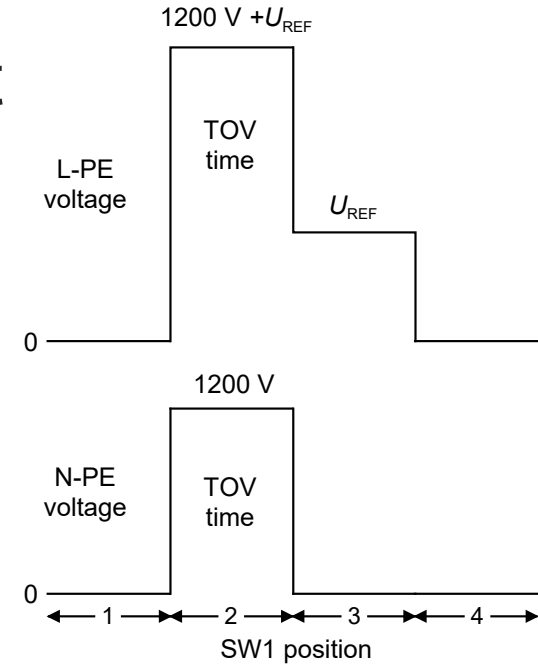
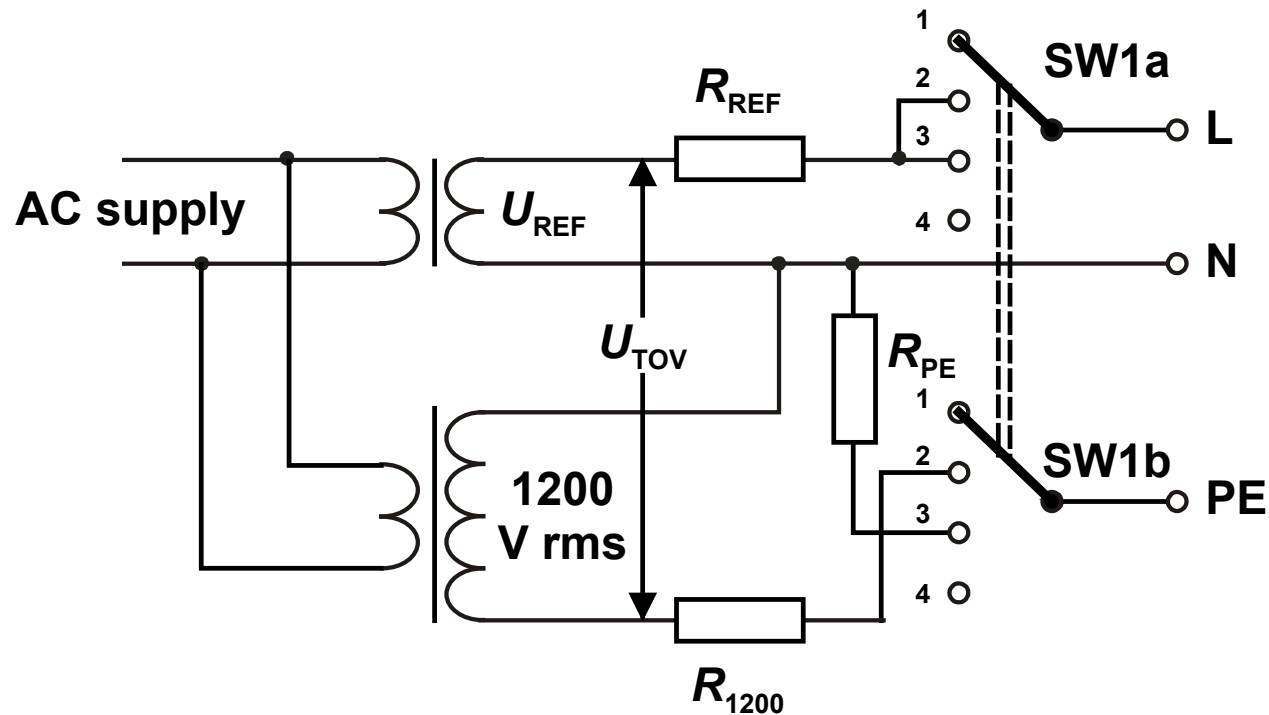


For U_{REF} , U_{TOV} , TOV time, R_{REF} and R_{TOV} details see IEC 61643-11: 8.3.8.1

G.8.2 Safeguards against fire

G.8.2.3, IEC 61643-11 8.3.8.2 high voltage system fault TOVs

- IEC 61643-11: 8.3.8.2 example test circuit



For U_{REF} , U_{TOV} , TOV time, R_{REF} , R_{1200} and R_{TOV} details see IEC 61643-11: 8.3.8.2

G.8.2 Safeguards against fire

Table G.10 summarizes G.8.2.2 and G8.2.3 testing

Maximum continuous AC voltage of varistor	Connection between		
	L to N or L to L	L to PE	N to PE
$1.25 \times V_r$ to $2 \times V_r$	G.8.2.2	G.8.2.2 and G.8.2.3	G.8.2.2 and G.8.2.3
$> 2 \times V_r$ to $1200 + 1.1 \times V_r$	No test	G.8.2.3	G.8.2.3
$> 1200 + 1.1 \times V_r$	No test	No test	No test
Overvoltage protection circuit with series 5.5.7 GDT and varistor	No test	No test	No test

V_r is the equipment rated voltage or the upper voltage of the rated voltage range



B.4 Simulated single fault conditions

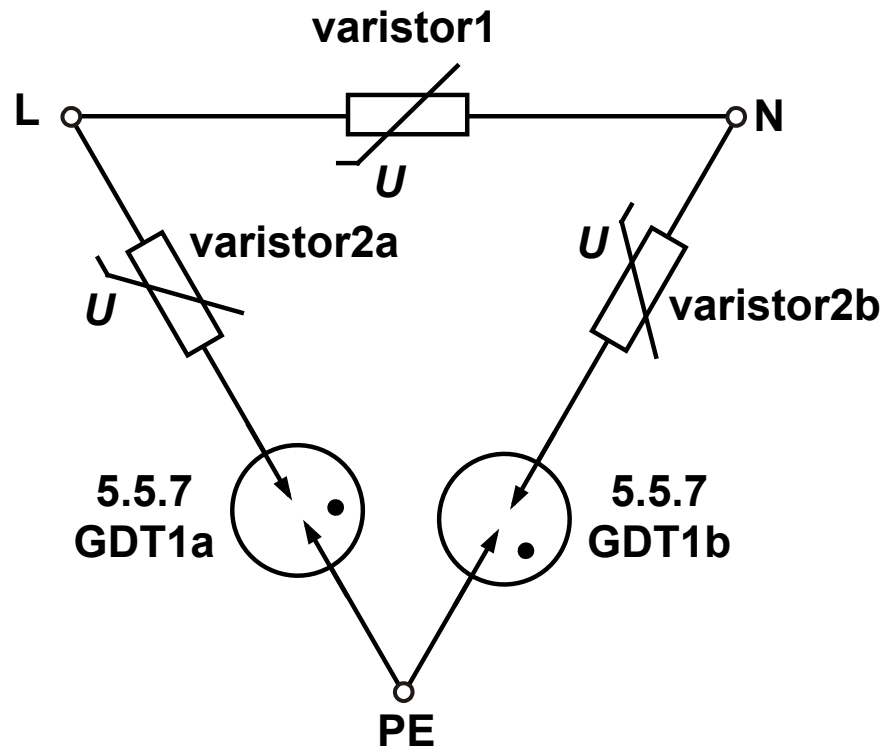
The effect of a single component failure simulated by short-circuiting any two leads and open-circuiting any one lead of the component one at a time needs to be considered. These single fault conditions do not apply to components that serve as a safeguard (interposing a barrier between a body part and the energy source, see 4.1.2 Use of components) complying with the relevant requirements of Annex G *Components* or with the safety requirements of the relevant IEC component standard. Component evaluations include:

B.4.5 Short-circuit and interruption of electrodes in tubes and semiconductors and tubes and
B.4.6 Short-circuit or disconnection of passive components (includes VDRs).

Excluded from these single fault simulations are components that serve as a safeguard complying with the relevant requirements of Annex G. Based on this, the series 5.5.7 GDT should be excluded because it is a mandated basic (insulation) safeguard against an unreliable PE connection. Varistors are not safeguards being classified a PIS (also covered as VDRs in B.4.6) and should be safety evaluated for open- and short-circuit connections.

Protection circuit design example 1

2-terminal design

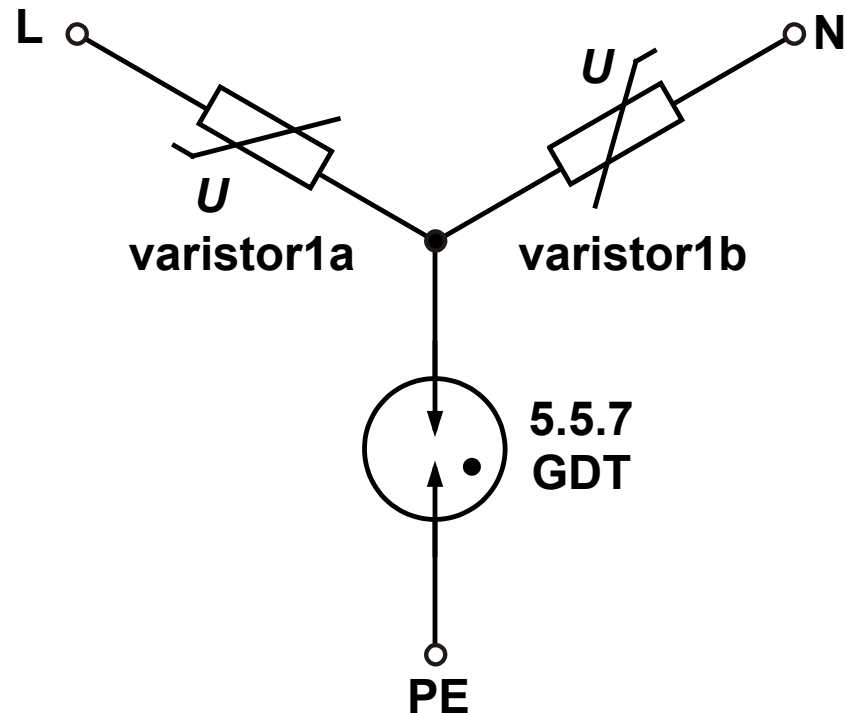


L to N protection: path varistor1. Standard varistor if $MCOV > 2V_r$. If $1.25V_r < MCOV < 2V_r$, the G.8.2.2 test results determine varistor type and required support items. To cope with B.4 *simulated single fault conditions* some form of equipment overcurrent protection needed.

L to PE and N to PE protection: series paths varistor 2a plus 5.5.7 GDT1a and varistor 2b plus 5.5.7 GDT1b. Standard varistor with a clamping voltage sufficient to prevent any continuous GDT conduction. The GDT is a safeguard and avoids B.4 *simulated single fault conditions* examination.

Protection circuit design example 2

3 terminal design



L to N protection: series path varistor1a plus varistor1b. Standard varistor if $MCOV > V_r$. If $0.625V_r < MCOV < V_r$ G.8.2 test results determines varistor type and required support items. Only one varistor shorted for B.4 *simulated single fault conditions* and making $MCOV > 1.25V_r$ avoids equipment overcurrent protection for a varistor short-circuit.

L to PE and N to PE protection: series paths varistor 1a plus 5.5.7 GDT and varistor 1b plus 5.5.7 GDT. Standard varistor with a clamping voltage sufficient to prevent any continuous GDT conduction. The GDT is a safeguard and avoids B.4 *simulated single fault conditions* examination.



Equipment insulation withstand voltage

- AC dielectric strength/withstand (HiPot) testing after equipment manufacture typically uses 1.5 kV a.c. (2.1 kV peak). Disconnecting overvoltage protection across the insulation barrier is allowed, but is inconvenient.
- The 5.5.7 GDT allows such testing to be done without disconnections. It means that 230 V a.c. insulation must be rated above 2.5 kV peak and IEC 60664-1 recommends an impulse verification level near to 2.9 kV peak for a 2.5 kV peak insulation rating
- Some designs may put the protection cost into insulation and increase the withstand rating from overvoltage category II (2.5 kV) to overvoltage category III (4 kV) or IV (6 kV). L to N overvoltage protection would still need to be considered.



Interpretations

- There are certain situations where a standard isn't sufficiently definitive or plain wrong. In those cases interpretations can be made based on the spirit of the standard and its normative documents. Interpretations may vary depending on who makes them.
- The content of this presentation is of a general nature only and is not intended to address the specific circumstances of any particular individual or entity; nor be necessarily comprehensive, complete, accurate or up to date; nor represent professional or legal advice.

Questions?