Overvoltage Categories and their Implication in the Specification of Power Supplies

An overview of a publication by
The European Power Supplies Manufacturers' Association EPSMA

www.epsma.org

The EPSMA – who we are

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  - Formed 1995
  - Around 30 members – major European power companies

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- Webinar presenter: Paul Lee - EPSMA administrator

The webinar subject – ‘Overvoltage Categories and their Implication in the Specification of Power Supplies’

- Summary of an EPSMA paper published 2022 for ‘members only’

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- Provides details of requirements for power conversion products installed in different OVC areas
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The paper

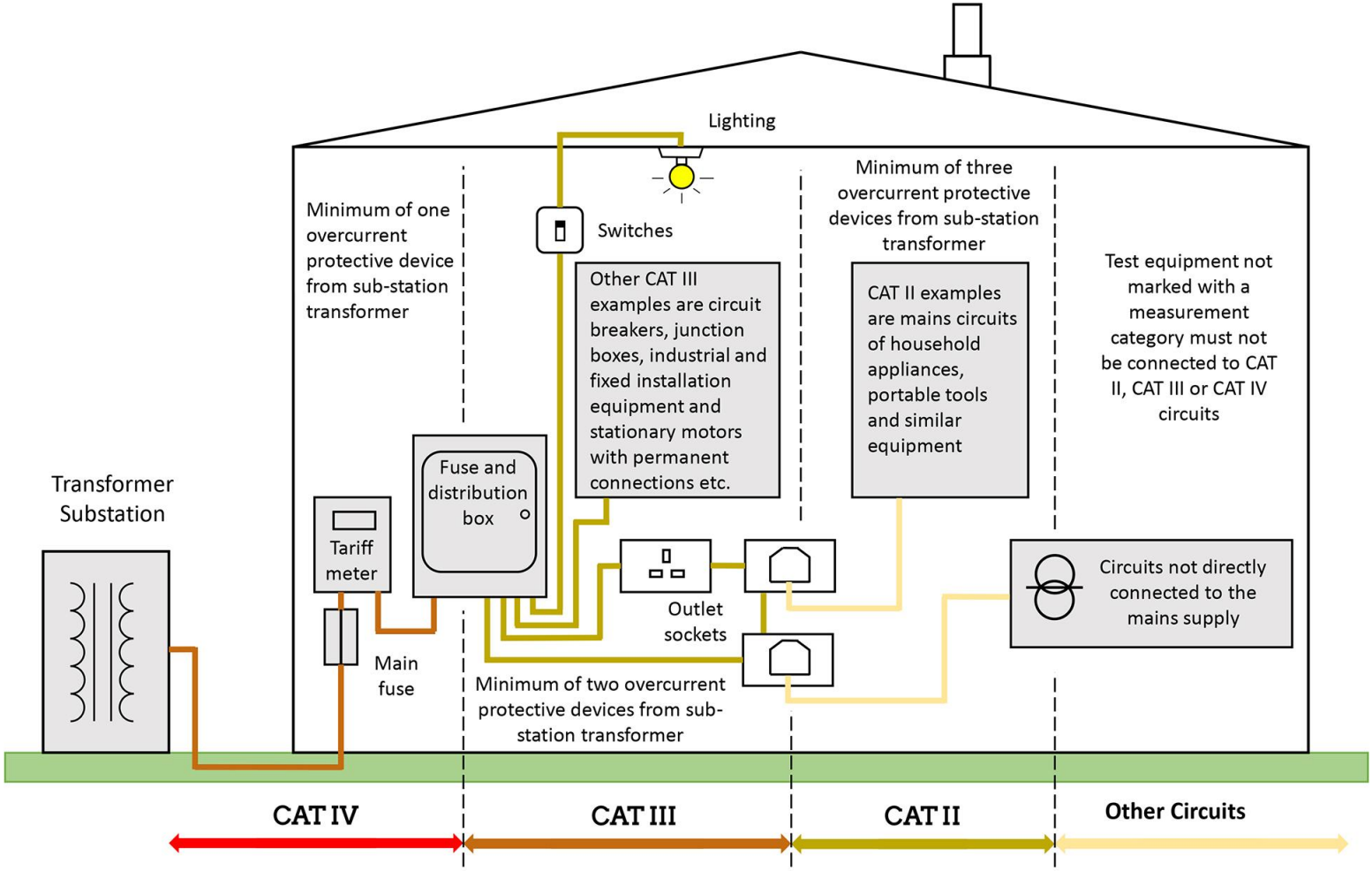
- Written for EPSMA members' internal use
- 19 pages, 9 tables, 3 figures
- Abstract available to view on www.epsma.org
- Full document available to non-members on application to secretariat@epsma.org (not for further distribution)

Index of the referenced paper

OVC- what does it mean?

- Over Voltage Category (OVC) is a numeral defining transient overvoltage conditions from e.g. lightning strikes or other sources (IEC 60664-1-2020)
- Categories relate to ‘installation’ position in an AC or DC power supply and distribution network
- **Category I** defined for equipment not connected to the electricity supply, through **Category IV** for connections to equipment before the incoming metering and fusing in a building

The four OVC categories



The over-voltages

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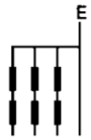
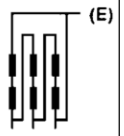
The over-voltages

- IEC 60664-1:2020 defines the voltage which equipment must withstand (not expected transient voltage) in each of the four categories
- The withstand voltages also depend on nominal system voltage (AC or DC) listed in the standard

The over-voltages – IEC 62368-1

Voltage line-to-neutral derived from nominal voltages AC or DC up to and including[a]	Nominal voltages presently used in the world				Rated impulse withstand voltage for equipment[a]			
	Three-phase four-wire systems with earthed neutral 	Three-phase three-wire systems earthed or unearthed 	Single-phase two-wire systems AC or DC 	Single-phase three-wire systems AC or DC 				
					Overvoltage category			
V	V	V	V	V	I	II	III	IV
50			12,5 24 25 30 42 48	30 to 60	330	500	800	1 500
100	66/115	66	60		500	800	1 500	2 500
150	120/208 [b] 127/220	115, 120, 127	100 [c] 110, 120	100 to 200[c] 110 to 220 120 to 240	800	1 500	2 500	4 000
300	220/380, 230/400 240/415, 260/440 277/480	200 [c], 220, 230, 240 260, 277	220	220 to 440	1 500	2 500	4 000	6 000
600	347/600, 380/660 400/690, 417/720 480/830	347, 380, 400 415, 440, 480 500, 577, 600	480	480 to 960	2 500	4 000	6 000	8 000
1 000		660 690, 720 830, 1 000	1 000		4 000	6 000	8 000	12 000
1 250 [d]			1 250	1 250	4 000	6 000	8 000	12 000
1 500 [d]			1 500	1 500	6 000	8 000	10 000	15 000

[a] These columns are taken from Table F.1 in which the **rated impulse withstand voltage** values are specified.

[b] Practice in the United States of America and in Canada.

[c] Practice in Japan.

[d] Only applicable for direct current.

Power Supply ratings

- Most commercially available PSUs are designed for the largest market e.g. OVC II
- PSUs can be used in higher OVC category than designed, with the addition of ‘Surge Protective Devices’ (SPDs)
- Most common requirement is to add SPDs to enable an OVC Cat II part to be used in a CAT III environment e.g. smart meter PSU, EV charger aux supply, some IOT applications

Designing for OVC - IEC 62368-1 clearances

- Determine transient level from Table 1 (slide 9)
- Table 3 in IEC 62368-1 then defines clearances depending also on altitude, pollution degree of environment and isolation grade e.g. basic/reinforced

Determining Clearance Distances – IEC 62368-1

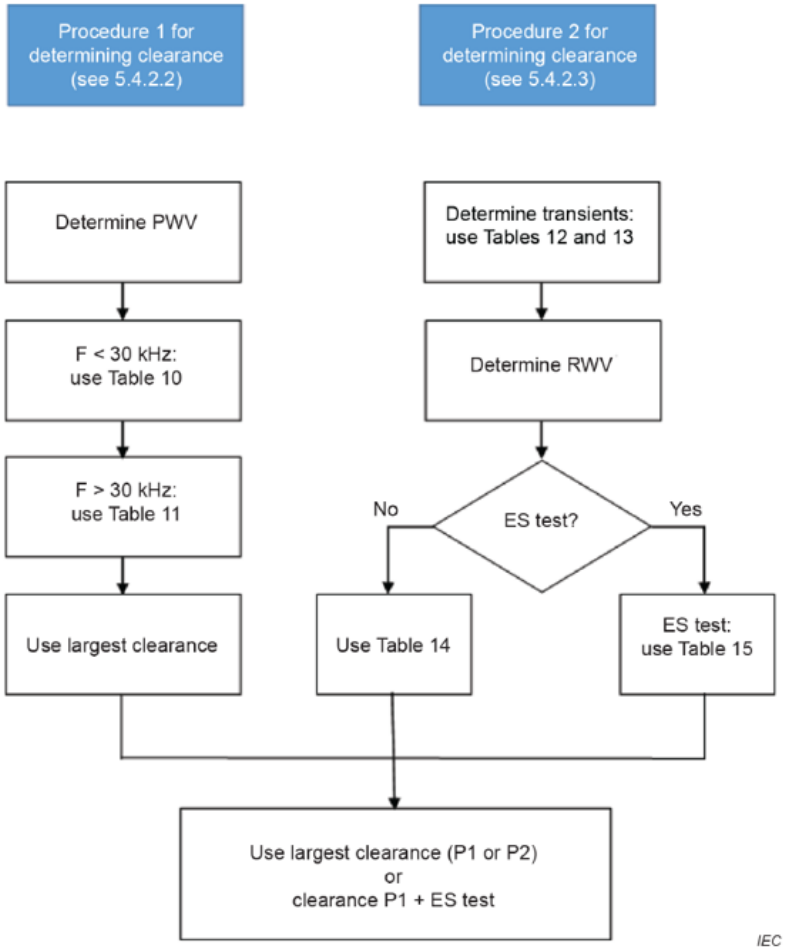


FIG 3: Flowchart for determination of required clearances according to IEC 62368-1:2018

Designing for OVC - IEC 62368-1 example clearances

Parameters of PSU	Required clearance for OVC II	Required clearance for OVC III	Required clearance for OVC IV
100-240V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 1,5mm RI: 3,0mm (P2 worse case)	BI: 3,0mm RI: 5,5mm (P2 worse case)	BI: 5,5mm RI: 8,0mm (P2 worse case)
100-120V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 1,27mm RI: 2,54mm (P1 worse case)	BI: 1,5mm RI: 3,0mm (P2 worse case)	BI: 3,0mm RI: 5,5mm (P2 worse case)

Designing for OVC - IEC 62368-1 solid insulation tests

- Thickness of insulation not affected by OVC Cat level
- Electric strength test is affected. E.g.

Parameters of PSU	Required electric strength test for solid insulation for OVC II	Required electric strength test for solid insulation for OVC III	Required electric strength test for solid insulation for OVC IV
100-240V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 2,5kVpk RI: 4,0kVpk	BI: 4,0kVpk RI: 6,0kVpk	BI: 6,0kVpk RI: 8,0kVpk
100-120V PWV: 800Vpk Altitude 2000m PD2	BI: 1,5kVpk RI: 2,5kVpk	BI: 2,5kVpk RI: 4,0kVpk	BI: 4,0kVpk RI: 6,0kVpk

Designing for OVC - IEC 62368-1 Component requirements

- X Capacitors (Line to line)
- Y Capacitors (Line to ground)
- Transformers with Triple Insulated Wire (TIW)
- Optical/Digital isolators
- Note: Transformers with fully insulated wires (FIW) are limited to OVC II applications

Designing for OVC - IEC 62368-1 ‘X’ Capacitors

- OVC II – (2.5kV max) A single X2-rated capacitors is allowed
- OVC III – (4kV max) Either a single X1 capacitor or 2 x series X2 capacitors

Capacitor subclass according to IEC 60384-14	Rated voltage of the capacitor V RMS	Type test impulse test voltage of the capacitor kV peak	Type test RMS test voltage of the capacitor kV RMS
Y1	Up to and including 500	8	4
Y2	Over 150 up to and including 300	5 [a]	1,5
Y4	Up to and including 150	2,5	0,9
X1	Up to and including 760	4 [a]	-
X2	Up to and including 760	2,5 [a]	-

Designing for OVC - IEC 62368-1
‘Y’ Capacitors (system voltage <250V)

- OVC II (2.5kV max)
  - Basic insulation – single Y2 capacitor
  - Reinforced insulation – Single Y1 capacitor or 2 x series Y2 capacitors
- OVC III (4kV max)
  - Basic insulation – single Y2 capacitor
  - Reinforced insulation – Single Y1 capacitor or 2 x series Y2 capacitors
- OVC IV (6kV max)
  - Basic insulation - single Y1 capacitor or 2 x series Y2 capacitors
  - Reinforced insulation – Single Y1 capacitor or 2 x series Y2 capacitors

Designing for OVC - IEC 62368-1 ‘Y’ Capacitors (system voltage >250V<300V)

- OVC II (2.5kV max)
  - Basic insulation – single Y1 capacitor or 2 x series Y2 capacitors
  - Reinforced insulation – Single Y1 capacitor or 3 x series Y2 capacitors
- OVC III (4kV max)
  - Basic insulation – single Y1 capacitor or 2 x series Y2 capacitors
  - Reinforced insulation – Single Y1 capacitor or 3 x series Y2 capacitors
- OVC IV (6kV max)
  - Basic insulation – single Y1 capacitor or 2 x series Y2 capacitors
  - Reinforced insulation – Single Y1 capacitor or 3 x series Y2 capacitors

Designing for OVC - IEC 62368-1 Triple Insulated Wire

- Wire that is certified for OVC II application might not be acceptable for OVC III applications
- As an example, insulation of a twisted pair made of TIW according to IEC 60851-5:2008 for reinforced insulation must pass 8,4kVpk for OVC II applications, 12kVpk for OVC III applications and 16kVpk for OVC IV applications

Designing for OVC- IEC 62368-1 Optical/digital isolators – parts complying with IEC 60747-5-5/-17

For isolators rated <250VAC and for reinforced insulation:

- For OVC II applications, an optical isolator must be rated 4kV pk minimum
- For OVC III applications, an optical isolator must be rated 6kV pk minimum
- For OVC IV applications, an optical isolator must be rated 8kV pk minimum
- The requirements are the same for digital isolators except that they must comply with IEC 60747-17 standard instead of IEC 607475-5-5

Designing for OVC- IEC 62368-1 Optical/digital isolators – cemented joints test method

For isolators rated <250VAC and reinforced insulation, after thermal cycling -

- For OVC II applications, an optical isolator must pass an electric strength test of 6,4kVpk
- For OVC III applications, an optical isolator must pass an electric strength test of 9,6kVpk
- For OVC IV applications, an optical isolator must pass an electric strength test of 12,8kVpk
- The requirements are the same for digital isolators except that they must comply with IEC 60747-17 standard instead of IEC 607475-5-5.

Designing for CAT III compared with CAT II - IEC 62368-1

- IEC 62368-1 is the standard for ICT and audio/video safety, effectively replacing IEC 60950-1 and IEC 60065
- ‘Default’ safety standard for many commercial and industrial PSUs
- If an SPD is not used to reduce transients, a CAT III PSU, compared with Cat II must have:
  - Increased clearance distances
  - Higher electric strength test of solid insulation
  - Higher rated components (X, Y caps, isolators)

Designing for OVC by reducing transients IEC 62368-1

- For *outdoor* equipment transients can be reduced by an internal SPD
- For *indoor* equipment it is not allowed to reduce transient levels by internal SPDs (VDR, GDT etc) to pass the OVC tests
- Any SPD fitted internally *must be disconnected* for the OVC tests
- Transients can be reduced by eg isolation transformer or EMI filter
- Latest edition IEC 62368-1 4th edition still not clear on the topic
- How to deal with a product with a certified SPD fitted internally?

Using an OVC CAT II PSUs in a CAT III/IV environments using SPDs

- For *outdoor* equipment SPD can be internal
- For *indoor* equipment SPD must be external
- SPDs must comply with IEC 61643 series of standards
- Degradation or failure of the SPD not considered in IEC 62368-1 (!)
- SPDs rated Type 2 and Type 3 according to IEC 61643-1 may be suitable
- SPD requirements described in IEC 62368-1 Annex G8

Using an OVC CAT II PSUs in a CAT III/IV environments using SPDs

SPD parameters:

- max continuous operating voltage *Uc*
- Voltage protection level *Up*
- Nominal discharge current *In* (Type 2)
- Open circuit voltage of a combination wave generator *Uoc* (Type 3)

Selecting an external SPD

- *Up*: For OVC II must be <2.5kV
- *Uc*: As high as possible for max lifetime
- *In* – Minimum value not clearly specified in IEC 62368. Typical values for a Type 2 SPD are 2, 3, 5kA
- *Uoc*:
  - OVCIII to OVC II – 10 x 4kV, 8/20us pulse with peak current ~2kA
  - OVC IV to OVC III – 10 x 6kV, 8/20us pulse peak current ~3kA

Typical values for a Type 3 SPD are 4, 6, 8, 10kV

IEC 61010-1 requirements

- Some differences to IEC 62368-1
  - Eg: determination of safety distances
  - Some less strict requirements for components compared with IEC 62368-1

IEC 61010-1 requirements – safety distances - examples

Annex K of IEC 61010 outlines a calculation method to find clearance – results in different values to IEC 62368-1 e.g.

Parameters of PSU	Required clearance for OVC II	Required clearance for OVC III	Required clearance for OVC IV
100-240V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 2,1mm RI: 4,1mm	BI: 3,5mm RI: 6,9mm	BI: 6,1mm RI: 12,1mm
100-120V PWV: 800Vpk Altitude 2000m PD2	BI: 1,4mm RI: 2,8mm	BI: 2,2mm RI: 4,4mm	BI: 3,7mm RI: 7,4mm

IEC 61010-1 requirements – safety distances – 62368 and 61010 compared

Parameters of PSU	Required clearance for OVC II	Required clearance for OVC III	Required clearance for OVC IV
100-240V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 2,1mm RI: 4,1mm	BI: 3,5mm RI: 6,9mm	BI: 6,1mm RI: 12,1mm
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IEC 61010-1

Parameters of PSU	Required clearance for OVC II	Required clearance for OVC III	Required clearance for OVC IV
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100-120V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 1,27mm RI: 2,54mm (P1 worse case)	BI: 1,5mm RI: 3,0mm (P2 worse case)	BI: 3,0mm RI: 5,5mm (P2 worse case)

IEC 62368-1

IEC 61010-1 requirements – solid insulation electric strength tests

Parameters of PSU	Required electric strength test for solid insulation for OVC II	Required electric strength test for solid insulation for OVC III	Required electric strength test for solid insulation for OVC IV
100-240V, 50-60Hz PWV: 800Vpk Altitude 2000m PD2	BI: 1,74kV RI: 3,0kV	BI: 2,45kV RI: 3,92kV	BI: 4,4kV RI: 7,1kV
100-120V PWV: 800Vpk Altitude 2000m PD2	BI: 1,35kV RI: 2,7kV	BI: 1,80kV RI: 2,86kV	BI: 2,54kV RI: 4,1kV

IEC 61010-1 and IEC 62368-1 solid insulation electric strength tests compared

Parameters of PSU	Required electric strength test for solid insulation for OVC II	Required electric strength test for solid insulation for OVC III	Required electric strength test for solid insulation for OVC IV
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IEC 61010-1

Parameters of PSU	Required electric strength test for solid insulation for OVC II	Required electric strength test for solid insulation for OVC III	Required electric strength test for solid insulation for OVC IV
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100-120V PWV: 800Vpk Altitude 2000m PD2	BI: 1,5kVpk RI: 2,5kVpk	BI: 2,5kVpk RI: 4,0kVpk	BI: 4,0kVpk RI: 6,0kVpk

IEC 62368-1

IEC 61010-1 requirements – Components: Safety Capacitors

- X Capacitors: No specific requirements except conformance with IEC 60384-14 and ‘adequately’ rated
- Y capacitors: Compliance with IEC 60384-14 in accordance with its rating

IEC 61010-1 requirements – Components: TIW

- No specific requirements for TIW except insulated wire should be ‘properly’ rated and withstand ‘appropriate’ electric strength test
- In practice use rules in IEC 62368-1

IEC 61010-1 requirements – Components: Optical Isolators

- No mention of specific requirements
- In practice follow IEC 62368-1

IEC 61010-1 Use of an OVC CAT II PSU in CAT III/IV environments

- SPD must be a VDR complying with IEC 61051-2 in a mains circuit
- OVC CAT II is as below - 5 positive and 5 negative impulses

Line-to-neutral MAINS voltage V r.m.s. or d.c.	Impulse withstand voltage V
≤50	500
>50 ≤ 100	800
>100 ≤ 150	1 500
>150 ≤ 300	2 500
>300 ≤ 600	4 000
>600 ≤ 1 000	6 000

IEC 61010-1 Use of an OVC CAT II PSU in CAT III/IV environments

If an SPD is used to enable reduced clearances, a risk assessment must be performed

Voltages must be reduced to the intended level *even under single fault conditions*

Implies inclusion of redundancy in transient limiting circuits

Paper Conclusions

- Both standards contain clear requirements for clearances and creepage distances for higher OVC. Standards have the same definition for OVC but have different approaches for determination of required clearances and determination of electric strength test for solid insulation.

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- Regarding requirements for components and solid insulation, standard IEC 61010-1 is outdated. There are no clear requirements stated for acceptance of components for higher OVC.

- For components, IEC 62368-1 is clearer and provides more information on how to select them.

- Some requirements are still not exact and some, especially in IEC 62368-1, are subject to further change (e.g. reducing internal transients with an SPD).

Thank you

Questions?