Decouplers, Couplers and Back-Filters for Surge Testing a DC Supply Interface

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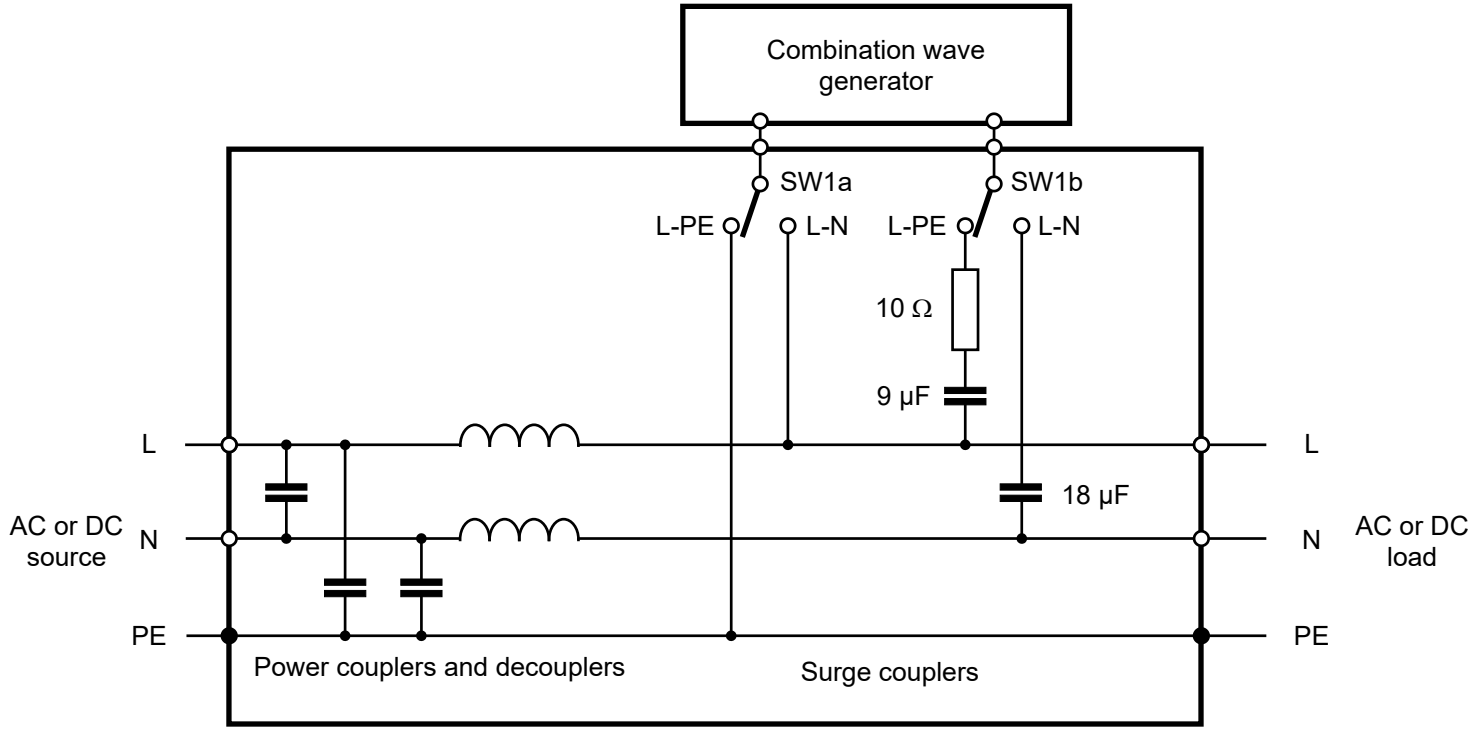
Items leading to this point

- IEC 61000-4-5, Ed. 3
- GR-1089-CORE, Issue 7
- Contributions made to ITU-T (ITU-T K Suppl. 15)
- Papers, ancient and modern
- ITU-T Recommendations K.20 and K.44 (10/18)
- This presentation

Typical EMC test arrangement for AC/DC powering



AC and DC power port couplers and decouplers based on IEC 61000-4-5 Figures 5 and 6. (N-PE test not shown)

- Why only L-PE and N-PE and not L+N-PE (common-mode)?
- Why is prospective current L-N 6 times more than L-PE and N-PE?

IEC 61000-4-5:2014, Ed. 3, Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test

- A complaint was made to the IEC that the new Ed.3 waveform requirements could make some Ed.2 surge generators non-compliant. This was robustly denied by SC 77B.

- Various organisations also voiced similar concerns (see following slides). CISPR/1365/INF identified generators are not compliant to Edition 3. According to the generator manufacturers, the specific Edition 2 models mentioned can be modified in order to meet the requirements of IEC 61000-4-5 Edition 3.

- As a result SC 77B issued 77B/778/INF (2017-06-02), which stated “As previously stated by SC77B MT12, it is not necessary to purchase a new generator to apply Edition 3 when a generator, which meets the requirements of Edition 2 is available. However, modification of some generators may be required.

Reaction to IEC 61000-4-5:2014, Ed. 3

IEC の他の TC

2015 年の秋頃、IEC SC37A（Low-voltage surge protective devices）では、IEC 61000-4-5 Ed.3 をここで作成する規格に引用しないことを決めたというメールがMT12 に報告された。波形自体は変更していないことは理解しても、サージ防護デバイスの規格では、1.2/50 μs（8/20 μs）サージ波形以外にも 10/250 μs，10/350 μs などの異なる波形も扱っており、1.2/50 μs（8/20 μs）だけ波形の規定方法が異なり混乱するとの理由による。今後 SC37A では、通信・信号用サージ防護デバイス（SPD: Surge Protective Devices）の規格だけでなく、電源用 SPD も含めて検討する。

CISPR

2016 年 11 月 に、IEC 61000-4-5 Ed.3 の改正に対する各国試験所に対してサージ試験器の校正結果及び買い替え等の状況を調査するアンケートをCISPR 文書（CISPR/1362/DC）として配信した。このアンケート結果をまとめた文書（CISPR/1365/INF）を 2017 年 2 月に発行し、そのまま適合するものや、改造、買い替えが必要かなどの具体的な結果が報告された。CISPR の結論として、IEC61000-4-5 Ed.3 適合に対して、改造又は買い替えが必要な試験器が存在するため、旧版（Ed.2）に対応した試験器が使えるように SC77B に規格を変更することを要求した。

ITU-T

ITU-T（国際電気通信連合）SG5 では、ITU-T　K.44（Resistibility tests for telecommunication equipment exposed to over-voltages and over-currents - Basic Recommendation） で、1.2/50 μs（8/20 μs）サージ発生器について、IEC 61000-4-5 を引用している。Ed.3 が発行されたことで ITU-T は、ITU-T K.96（2014）-Amendment 1 を発行し、IEC 61000-4-5 の Ed.2 とEd.3 の違いを明らかにするとともに、Ed.3 で改造の必要のない雷サージ試験器はそのまま使え、Ed.2 で校正された既存の雷サージ試験器の利用も可能としている。（但し 10/700μs サージ発生器は、ITU-T K.44にて独自の回路規定がされており、IEC 61000-4-5 の引用はしていない。）

Reaction to IEC 61000-4-5:2014, Ed. 3 (Google translate version)

Other TCs of IEC

Around the autumn of 2015, a mail stating IEC SC 37 A (Low-voltage surge protective devices) reported that it decided not to quote IEC 61000-4-5 Ed.3 to the standards created here was reported to MT 12. Understanding that the waveform itself is not changed, the surge protection device standard also supports different waveforms such as 10/250 μs and 10/350 μs in addition to the surge waveform of 1.2 / 50 μs (8/20 μs) It is handled, because it is confused because the regulation method of the waveform differs by only 1.2 / 50 μs (8/20 μs). SC37A will consider not only the standards for surge protection devices (SPD: Surge Protective Devices) for communication and signals but also the power supply SPD.

CISPR

As a CISPR document (CISPR / 1362 / DC), in November 2016, a questionnaire to survey the results of the calibration of the surge tester and the status of replacement etc. to each national laboratory for revision of IEC 61000-4-5 Ed.3 Delivered. A document (CISPR / 1365 / INF) summarizing the questionnaire result was issued in February 2017, and concrete results such as adaptation as it is, whether remodeling or replacement is necessary or not were reported. As a conclusion of CISPR, there are testers that need to be remodeled or replaced in accordance with IEC 61000-4-5 Ed.3 conformity, so the standards for SC77B are set so that testers corresponding to the old version (Ed.2) can be used I requested to change.

ITU-T

In the ITU-T (International Telecommunication Union) SG 5, 1.2 / 50 μs (8/20 μs) surge was measured by ITU-T K.44 (Resistivity tests for telecommunication equipment exposed to over-voltages and over-currents - Basic Recommendation) Regarding generators, IEC 61000-4-5 is cited. By issuing Ed.3, ITU-T issues ITU-T K.96 (2014) - Amendment 1 and clarifies the difference between Ed.2 and Ed.3 of IEC 61000-4-5 Along with Ed.3, lightning surge testers that do not need remodeling can be used as they are, making it possible to use existing existing lightning surge testers calibrated with Ed.2. (However, the 10/700 μs surge generator is proprietary circuit specification by ITU-T K.44, and quotation of IEC 61000-4-5 is not done.)

IEC 61000-4-5:2014, Ed. 3, DC powering test CDN problems identified by US National Committee (NC)

77B/734/DC (2015-05-15) quoted US NC findings

- Testing DC products in the current revision of IEC61000-4-5 is causing many field related problems for test labs and manufacturers. Many products will not power up through the power CDN in the standard and in some cases may be damaged by the inductance that is necessary to apply the surge.
  - By the nature of DC-DC inverters they require fast transitions in the input DC that often approach or exceed the blocking frequency of the inductors in the CDN.
  - Data centres are changing over from AC power to high voltage DC which will result in more DC powered products requiring testing.
  - Some DC distribution systems are closer to signal lines in respect appropriate testing impedance rather that AC power distribution circuits. (40 ohms rather that 0 and 10 ohms). It should be investigated if the AC CDN is actually the most appropriate method for DC networks.
  - DC supplies require a fast inrush current capability from the source in order to operate correctly. The inductors in the IEC 61000-4-5 CDN design block this fast inrush current and in some cases this may cause destructive oscillation of the supply.

IEC 61000-4-5:2014, Ed. 3, US NC reference to other DC test example standards

- Generic: EN 61000-6-1: 2005: Direct Reference to IEC61000-4-5. DC ports which are not intended to be connected to a DC distribution network are treated as signal ports. L-L and L-G
- Generic: EN 61000-6-2: 2005: Direct Reference to IEC61000-4-5. The test is applicable to DC power input ports intended to be connected permanently to cables longer than 3 m. L-L and L-G
- ITE: EN 55024: 2010: Direct Reference to IEC61000-4-5. The test is applicable to ports, which may connect directly to outdoor cables. L to G
- Railway: EN 50121-4: 2006, EN 50121-3-2: 2005, EN50155: 2007: Direct Reference to IEC61000-4-5. This test is intended to replicate the phenomena known as direct coupling.
    - When the power supply is isolated from earth, an output impedance of 42 Ω and a coupling capacitance of 0,5 µF are recommended.
    - When the power supply is not isolated from earth, an output impedance of 12 Ω and a coupling capacitance of 9 µF are recommended.
    - These requirements are for cable-length above 30 m. L-L and L-G
- Security: EN50130-4: 2011: Reference to IEC61000-4-5 with modifications. Extra low voltage and signal lines shall be subjected to transients injected by line-to-ground coupling mode only, with an output impedance of 42 Ω .

IEC 61000-4-5:2014, Ed. 3.1, (+Amendment 1:2017)

Rationale:

- The method for testing DC products in the current revision of IEC61000-4-5 is causing many field related problems for test labs and manufacturers. Many products will not power up through the power CDN in the standard and in some cases may be damaged by the inductance that is necessary to apply the surge (see 77B/734/DC for further information).The DC/DC converter problem is related to the switching of the converter which produces a voltage drop at the decoupling inductors on one hand and oscillations produced by the EUT impedance in combination with the source on the other hand. Measurements were performed using different brands of CDNs with a device known to show that problem as an EUT. The result shows different oscillations and signal forms of the voltage at the EUT for different CDNs. According to the outcome, the use of a CDN with a higher current rating (i.e. smaller decoupling inductivity) can solve the problem.
- At the meeting of SC77B/MT12 in Akishima, Japan on August 26, 2016, it was decided to add a statement into 7.3 allowing surge tests with higher current rated CDNs and to add a new Annex I to explain the problem in detail.

GR-1089-CORE, Issue 7

Early in 2018, I was alerted to the following:

- R4-26 [253] DC mains power ports (Type 8 and 8b ports) shall comply with the first-level criterion of Section 4.5.7, “Conformance Criteria,” when subjected to the applicable DC Mains tests described in ITU-T K.20. The equipment shall be tested to the applicable Enhanced Levels in the DC Power grounding configurations that apply. This requirement has an effective date of January 1, 2019.
  - NOTE 1: locations other than telecommunications centres (COs), GR-1089 applies K.20 regardless of where the equipment is intended to be installed. The test procedures and connection diagrams for K.20 are found in ITU-T K.44.
  - NOTE 2: however, there are some situations in OSP cabinets and at customer locations where floating DC Mains may exist or are prescribed by the manufacturer and need to be tested as such.

DC powering variants

- ITU-T K Suppl. 15 (09/2018) ITU-T K.20, K.21 and K.44 – Internal DC powering interface surge testing factors.

ITU-T K Suppl. 15 Table 1 – Port types		
DC Source Type	**Source earth-bonding**	**Load/feed earth-bonding**
Single polarity	none (floating)	none (floating)
		Positive polarity
		Negative polarity
	Positive polarity	none
		Positive polarity
	Negative polarity	none
		Negative polarity
Dual polarity (±)	0 V	none
		0 V (three wire system)
	Single polarity supply made to be balanced about earth potential by a high resistance voltage divider (essentially floating)	none

NOTE: Any external DC supply surge protective devices with earth bonding need to be included in testing

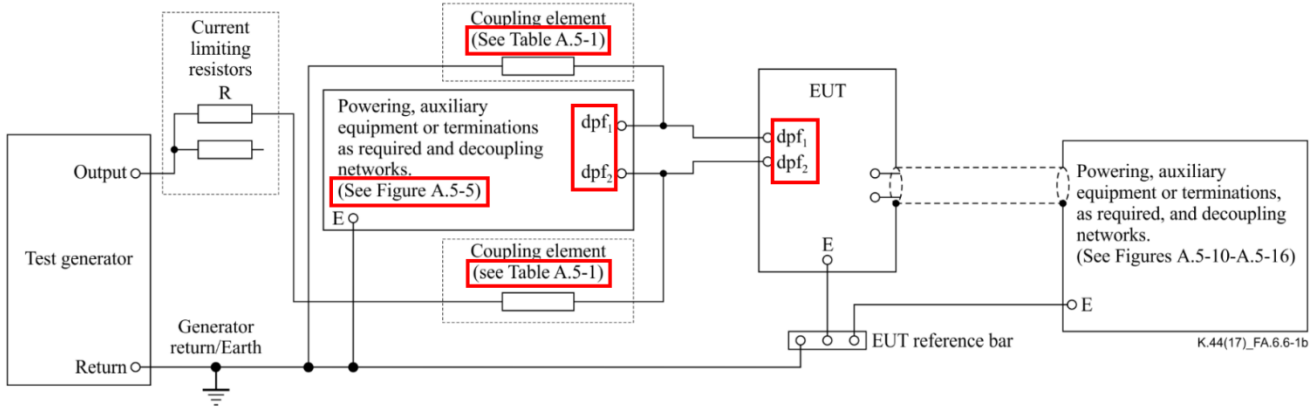
K Recommendation required actions by 01-01-2019

1. Understand the existing historical aberrations and errors in:
    1. Figures
    2. Terms
    3. Body text
2. Back out DC testing changes from 2016-06 to 2017-05 issues of ITU-T K Recommendations
3. Rework DC powering testing to comprehend ITU-T K Suppl. 15 Table 1 and simulation results.
4. Publish revised K Recommendations

K Recommendation existing historical errors — Term examples

- **d.c. power interface ports:** The port connects to a cable, e.g., a shielded cable which provides d.c. power, e.g., –48 V. (Generic definition)
- **dedicated power feed (dpf) port:** The port connects to a dedicated power feed
- **dedicated power feed (dpf):** A dedicated power feed is a power feed provided by a dedicated *telecommunications cable* which *leaves the building* and is used exclusively to provide the power feed. (Specific definition)

K Recommendation existing historical errors — Figure example



EUT earthing is as follows:
1) If the equipment has an earthing point, connect this point to the EUT reference bar;
2) If the equipment has a conductive case, but does not have an earthing point, connect the case to the EUT reference bar;
3) If the equipment has neither an earthing point nor a conductive case, let the equipment float.

Figure A.6.6-1b – Example of a test circuit for a transverse/differential overvoltage or overcurrent on a d.c. power interface port (dpf1 grounded)

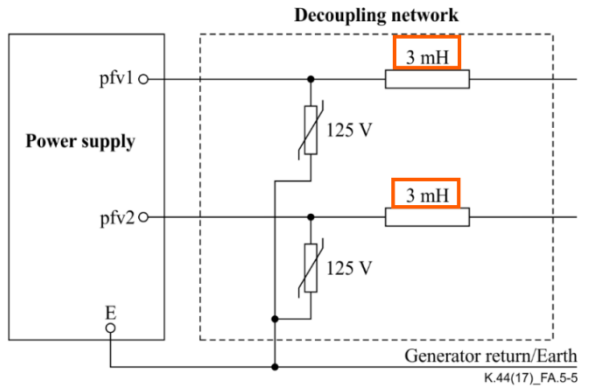


Figure A.5-5 – Decoupling network for AE connected to the tested external dpf pair port

Figures A.6.6-1a and A.6.6-1b are for transverse/differential surges.
Figure A.6.6-2 is for port to earth surges
All these Figures have the problems highlighted above

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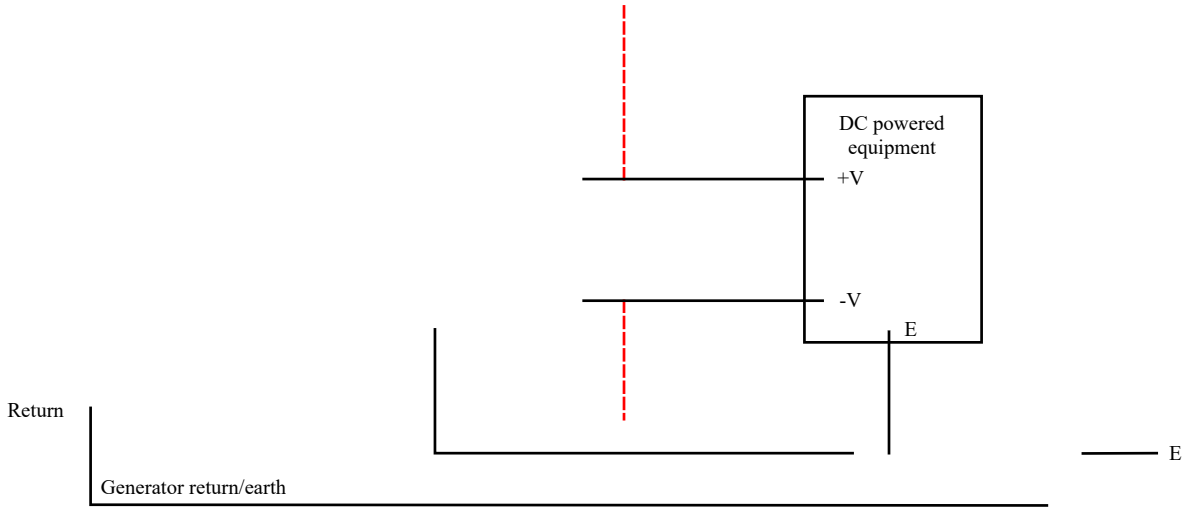
ITU-T K Suppl. 15, Internal DC powering interface surge testing factors (K.20, K.21 and K.44) — 1

The DC powering interface testing review looked at following factors

- Basic DC powering system type
  - Floating (no earth-bonding)
  - Polarity earth-bonded
- Port type
  - Sourcing power
  - Receiving power
- Port impedance response to surge conditions
- Type of surge test
  - Common-mode (port to earth)
  - Differential-mode (transverse)
  - Mixture of both common-mode and differential-mode
- Any surge protection functions present
- Inductance of the internal cable connecting the power source and the power load

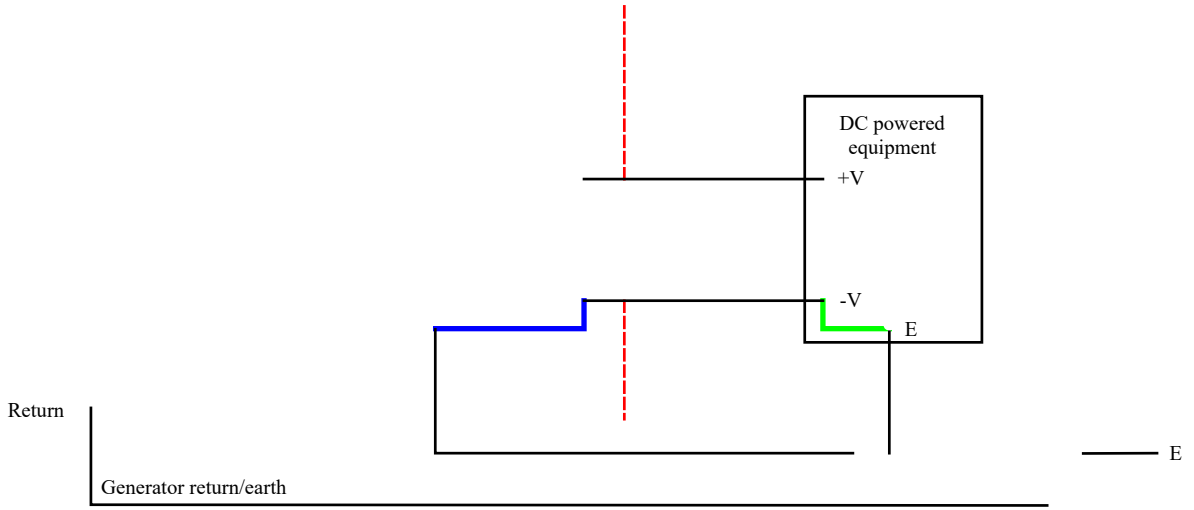
ITU-T K Suppl. 15, Internal DC powering interface surge testing factors (K.20, K.21 and K.44) — 2

A basic DC sourcing (red dotted surge connection) or receiving powering (black solid line surge connection) port test diagram. Covers floating (no earth-bonding) and polarity earth-bonded configurations and configures for common-mode (port to earth), differential-mode (transverse) or a mixture of both. CDN can reflect the actual connecting feed cable inductance (system test).



ITU-T K Suppl. 15, Internal DC powering interface surge testing factors (K.20, K.21 and K.44) — 3

Equipment supply polarity earth-bonding (examples are blue source and green powered connections) configures circuit from having a common-mode (port to earth) surge to differential-mode (transverse) surge by earth-bonding one surge feed. In operation, surge protection can also provide surge feed earth-bonding.



ITU-T K Suppl. 15, Internal DC powering interface surge testing factors (K.20, K.21 and K.44) — 4

The main contents of ITU-T K Suppl. 15 cover:

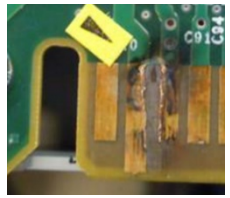
- Body text: Overview of generic test circuits and surge decoupling networks.
- Appendix I: Floating supply and powered equipment DC port surge conditions – circuit and waveforms
- Appendix II: Earth-bonded supply and powered equipment DC port surge conditions – circuit and waveforms
- Appendix III: Earth-bonded supply and powering source equipment DC port surge conditions – circuit and waveforms
- Appendix IV: Floating supply with external surge protection surge conditions – circuit and waveforms

NOTES
The DC powered equipment dynamic load variants of 100 µF or 10 Ω are used.
ITU-T K Suppl. 15 is a summarized version of ITU-T SG 5 2018-09 meeting contributions numbers C 291 to C 299 (Testing equipment-powering ports that are not connected to the AC mains supply – Parts 1 to 9.)

ITU-T K Suppl. 15, Internal DC powering interface surge testing factors (K.20, K.21 and K.44) — 5

Key points:

- Floating supplies will have an insulation withstand surge test



PCB arc damage on a 48 V DC system

- Polarity earth-bonding will convert the common-mode surge into a differential surge.
- If the polarity earth-bonding is not at the surged port, a mixture of common-mode and differential surge can occur at the surged port as the return current path is via the connecting cable.
- Besides using the expected connecting cable inductance, the older Recommendation K.44 3 mH value and commercial AC/DC CDNs are grandfathered.
- The surge voltages and currents at the equipment port will depend on the port dynamic impedance under surge conditions (capacitive, resistive or variable).
- Recommended external surge protection should be included in the test circuit.

Papers, ancient and modern — 1

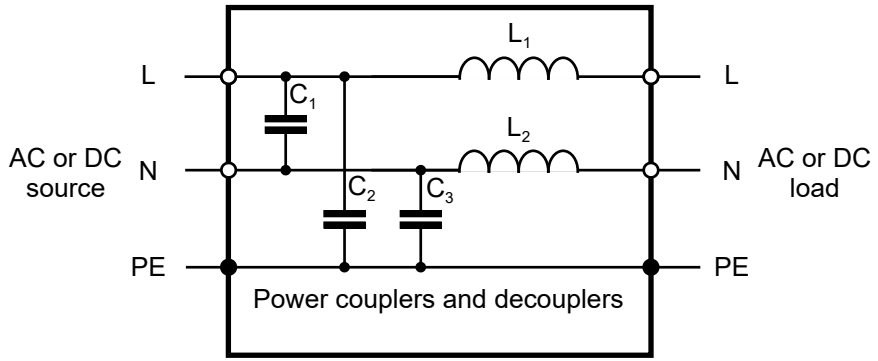
- Peter L Richman, Criteria and designs for surge couplers and back-filters. 202 - 207. 10.1109/National Symposium on Electromagnetic Compatibility.1989.37180

Classic paper on how to and how not to implement surge couplers and CDNs for EUT testing.

- Zhou Mi; Wang Jianguo; Liu Yang; Xiang Nianwen; Sun Zhen; Chen Junjie and Fang Chunhua, Coupling and decoupling network for surge immunity test on power lines, 2008 International Conference on High Voltage Engineering and Application, pp190-193

CDN and design details for IEC 61000-4-5.

CDN current rating A	L_1, L_2 mH	C_1, C_2, C_3 µF
<25	1.5	30
25 – 60	0.625	72
60 - 100	0.375	120



Papers, ancient and modern — 2

- Mi Zhou; Jianguo Wang; Xuan Fan; Li Cai; Chunhua Fang and Jian Xue, Influence of Power-Line Coupling/Decoupling Network on Output Characteristics of the Combination Wave Generator, IEEE Transactions on Power Delivery, 2011, Vol. 26, pp 2333-2341.

More CDN and design details for IEC 61000-4-5. For voltage waveform time to half value >40 μs L_1=L_2 > 0.6 mH.

These CDN design approaches try to minimise the degradation of the surge generator 1.2/50 voltage waveform by large values of series inductance and the level of surge waveform reaching the power source by large values of shunt capacitance. Although this approach maximises the surge stress on the EUT, it does not necessarily reflect system field conditions as noted by the IEC US National committee.

An alternative approach is to emulate the field system by making the CDN function the connecting cable impedance. This would distribute the surge stress across the system rather than solely to the EUT. The revised recommendations K.20 and K.44 have an option to do this.

ITU-T Recommendations K.20 and K.44

- Revised Recommendation K.20 was submitted on 10/18 and published 19-12-2018
- K.20/K.21 major changes were:
  - renaming of some test titles for clarity;
  - addition of DC power interface powering source test (Tables 1b and 7)

- Revised Recommendation K.44 was submitted on 10/18 and published 11-01-2019
- K.44 major changes were:
  - addition of new definitions and modifying one old definition;
  - clarification of main body text
    - 10.5.3 Floating DC power interface
    - 10.5.4 Earth-bonded DC power interface;
  - revision of the test schematics to improve clarity;
    - Figure A.5-9 (DC feed cable CDN)
    - Figure A.6.6-1a (DC powered equipment)
    - Figure A.6.6-1b (DC source equipment)

This presentation has covered

- IEC 61000-4-5, Ed. 3 – Testing exposed DC system CDN test problems
- GR-1089-CORE, Issue 7 – Referenced K.20 and K.44 for January 2019
- Contributions made to ITU-T SG 5 October meeting – Justifications for change (summarised in ITU-T K Suppl. 15)
- Papers, ancient and modern – Original intent of CDNs
- ITU-T Recommendations K.20, K.21 and K.44 – 10/18 DC interface test revisions, published by January 2019