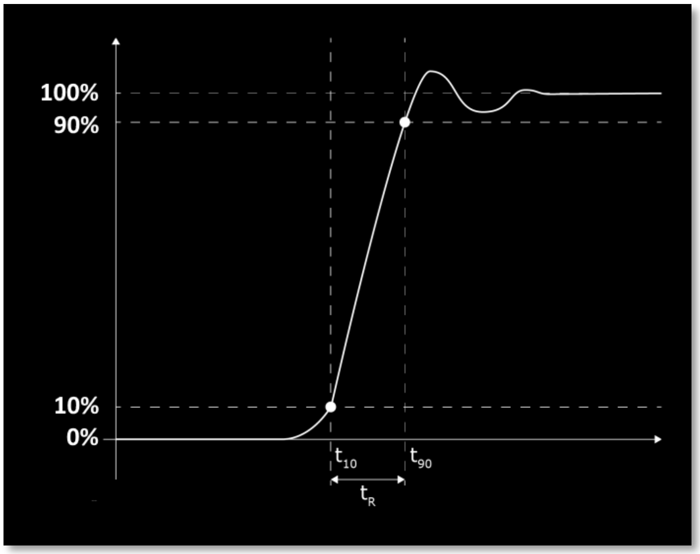
IEC 61000-4-11 & 34 Testing and AC Source Rise & Fall Time



RELEVANT IEC STANDARDS

- IEC61000-4-11
- IEC61000-4-34

AC VOLTAGE DIPS

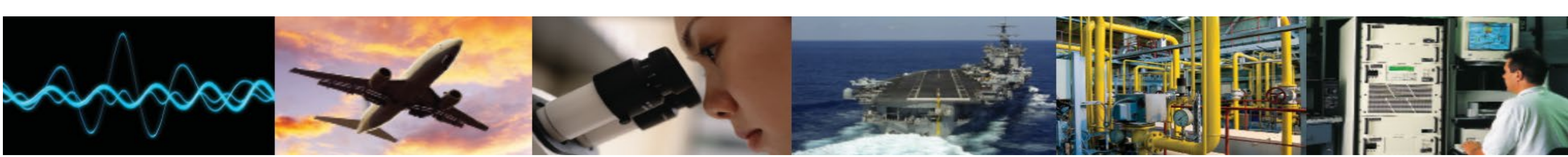
1 Preface

This application note reviews the AC source generator voltage rise and fall time requirements as covered by section 6.1.2, Table 4 of IEC test standard IEC61000-4-11 Ed. 3 and section 6.1.1, Table 4 of IEC61000-4-34. Also included is a review of IEC61000-4-11 Ed.3, Annex D, sections 3, 4 and 5 that address this requirement in more detail and provides a rationalization for it. This requirement can be confusing. Note that quoted sections of the actual IEC standards are highlighted using blue fonts in this application note.

2 Relevance

Before reviewing the voltage rise and fall time requirements of the AC power source used for voltage dips and interruptions testing, it is important to understand that for many product categories which require testing to IEC61000-4-11 or IEC61000-4-34, the phase angles called out for the **actual** tests are typically only 0° and 180°. While the generic -4-11 and -4-34 standards define other possible voltage interruption or dip phase angles like 90° and 270°, the actual test requirements for any given product are determined by their relevant IEC product category standard. This product standard in turn refers to the generic -4-11 and -4-34 standards for reference but dictates the actual test levels and test phase angles to be used. At the time of this writing, there are only a couple medical products that require testing for dips at 90 and 270 degrees.

Since at 0° and 180° phase angles the AC sine wave is at zero volts, there is no voltage level change at these phase angles the voltage slew rate requirement is irrelevant. The voltage will change at the rate of the AC sine wave and there is no abrupt voltage step as is the case at other phase angles like 90° and 270°. Thus, for test labs where the category of products that will be tested is known in advance, provisions to ensure the AC source used meets these slew rate requirements may not be relevant and can result in significant cost savings.



3 Pertinent Sections of both IEC Standards

This section contains the relevant sections of the IEC61000-4-11 (EUT's up to 16A/phase) and IEC61000-4-34 (EUT's > 16A/phase).

3.1 IEC61000-4-11 Section 6.1.2, Table 4, Text:

The relevant row of Table 4 states the following:

Voltage rise (and fall) time tr (and tf), see Figures 1b) and 2, during abrupt change, generator loaded with 100 Ω resistive load	Between 1 µs and 5 µs

Rationalization Annex D Text:

D.3 Rationale for the need of rapid fall-times

In case of short circuit in the line, the voltage at the input terminals of the equipment might go to zero in less than 5 µs. If the short circuit originates from the public network, the fall-time will be relatively slow, in the order of hundreds of microseconds to some milliseconds. If, however, the short circuit is at the local premise, for example due to the failure of another equipment installed in close proximity, the mains voltage will go to zero within microseconds, with fall-times shorter than 1 µs reported for some cases.

In this case, the input rectifier diodes of the equipment will be commutated from conduction mode to blocking mode with a sudden high reverse voltage due to that very fast voltage rise time. As those diodes are usually designed for natural line commutation with a rise-time of the voltage in the range of milliseconds, this event is an increased stress for the rectifier diodes. More generally, fast voltage transients can disturb electronics as well, leading to the damage of the equipment.

Tests performed with a fast fall-time in the range of a few microseconds emulating the short circuit condition can be used to test the robustness of equipment against fast transient short circuits of the line.

D.4 Interpretation of the rise-time and fall-time requirements during EUT testing

In 2010 an interpretation sheet for IEC 61000-4-11:2004 (second edition) was issued. The content of this sheet is as follows:

1) "In IEC 61000-4-11:2004, Table 4 does not apply to EUT (equipment under test) testing. Table 4 is for generator calibration and design only.
2) With reference to Table 1 and Table 2, there is no requirement in 61000-4-11:2004 for rise-time and fall-time when testing EUT; therefore, it is not necessary to measure these parameters during tests.
3) With reference to Table 4, all of the requirements apply to design and calibration of the generator. The requirements of Table 4 only apply when the load is a non-inductive 100 Ω resistor. The requirements of Table 4 do not apply during EUT testing."

D.5 Main conclusions

With respect to rise-time and fall-time, the main conclusions are the following:

- It is possible, for real-world voltage dips, to have fall-times faster than 5 µs in the case of short circuits close to the equipment. However, for the time being, this document does not consider the effects of voltage fall times shorter than 1 µs.
- Rise-time depends on several factors including the impedance of the network, cabling and equipment connected in parallel.

- The rise-time and fall-time requirements have remained unchanged and the document has been used worldwide since its first publication in 1994, but, as in the interpretation sheet, these rise-time and fall-time requirements do not apply during a test of an EUT. They only apply when calibrating a dip generator with a 100 Ω resistive load. These rise-times and fall-times do not necessarily occur during an actual EUT test.
- Most voltage dip and short interruption immunity tests begin and end at 0˚ or 180˚. Published research generally concludes that these are the most severe phase angles for voltage ride-through tests. Note that at 0˚ and at 180˚ the instantaneous waveform voltage is zero, so rise-time and fall-time have no meaning.
- Pre-compliance testing could be considered using a dip generator with a longer rise-time and fall-time up to 200 µs for voltage dip and short interruption tests that begin and end at 0˚ or 180˚, as rise-time and fall-time are not important at these angles. However, full compliance with the test methods of this document requires to use a generator that, when tested with a 100 Ω resistive load, meets the 1 µs to 5 µs requirement in 6.1.3.

3.2 IEC61000-4-34 Section 6.1.1, Table 4, Text:

The relevant row of Table 4 states the following:

Voltage rise (and fall) time tr (and tf), during abrupt change, generator loaded with resistive load – see NOTE A and NOTE 1	Between 1 µs and 5 µs for current ≤ 75 A Between 1 µs and 50 µs for current >75 A

NOTE A: These values must be checked with a resistive load as per NOTE 1 after this table, but they need not be checked when an EUT is connected.

NOTE 1: The value of the non-inductive resistive load for testing overshoot, undershoot, rise time, and fall time shall be 100 ohms for generators rated for 50 A or less, 50 ohms for generators rated for more than 50 A and less or equal than 100 A, and 25 ohms for generators rated more than 100 A.

Annex A, Section A.1 Test generator inrush current requirement

The test generator shall be capable of supplying the peak inrush current shown in Table A.1.

Rated current of Equipment	Minimum peak inrush current capability of the generator
16 A – 50 A	500 A
50,1 A – 100 A	1000 A
More than 100 A	Not less than 1000 A, and sufficient to maintain ±10 % of required voltage value during maximum peak inrush, measured as rms. value refreshed each ½ cycle per IEC 61000-4-30.

4 Voltage Rise and Fall Times when using EPTS Option

For Pacific Power Source ECTS2 Harmonics and Flicker test systems equipped with the Electronic Power Transfer Switch (EPTS) option, the requirement for voltage rise and fall time capability is handled by the EPTS hardware and **not** a function of the AC power source used for the test, provided that the power source output inductance is low enough to guarantee that it does not affect rise or fall times. Generally, a power source with < 100 µH will suffice to meet the < 5 us specification.

The transition times for voltage dips and interruptions is determined by the Solid State electronic switches that switch between the two AC (or DC for IEC61000-4-29) voltage sources. This requires synchronization of the programmable AC power source that provides the dips and interruption levels to the nominal voltage AC source, typically 230Vac and 50Hz or 120Vac and 60Hz provided by the local utility. This concept is illustrated in the figure below.

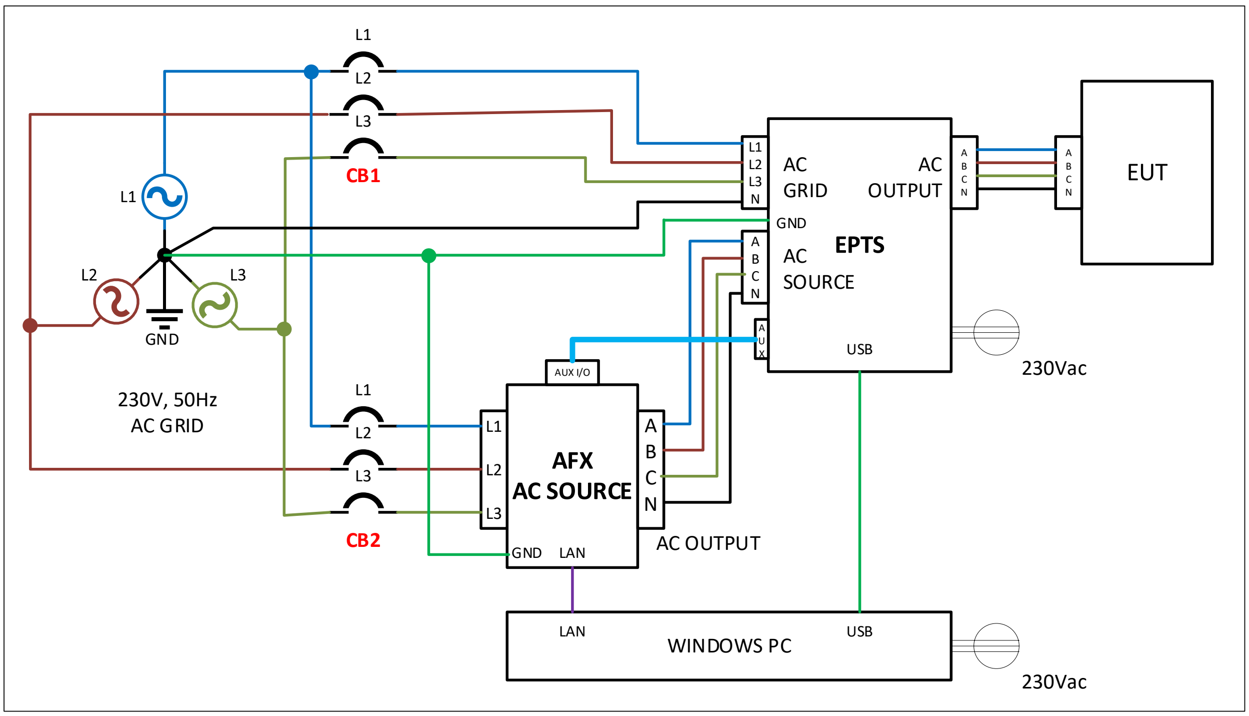


Figure 1: EPTS Option Block Diagram

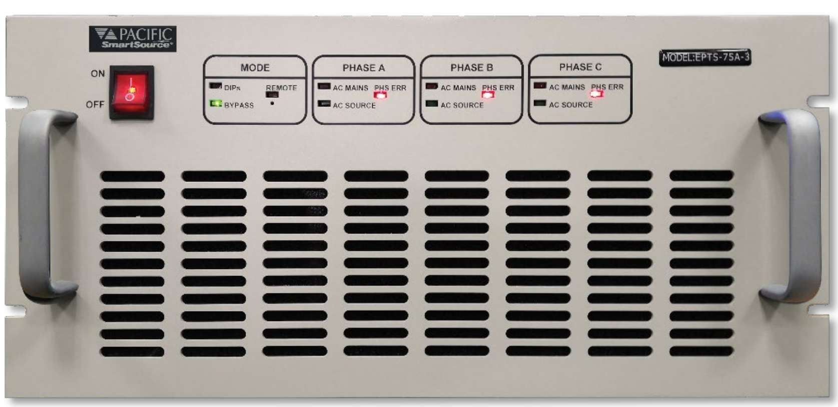


Table 1: EPTS Series Electronic Power Transfer Switch

The resulting voltage transients at 90° and 270° where the voltage slew rates have to be fast enough to meet the < 5 µsec rise and fall times. For the case of 230Vac nominal voltage, the resulting voltage waveforms for the EPTS are shown in the two scope images below.

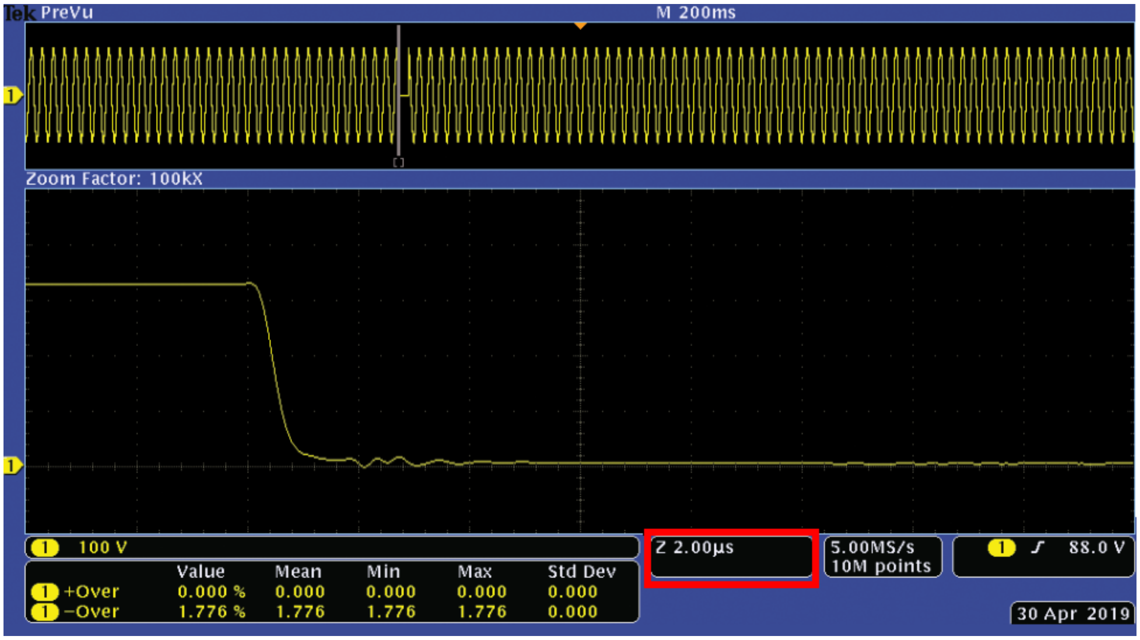


Figure 2: EPTS Voltage Fall Time at 90° = 2 µsec

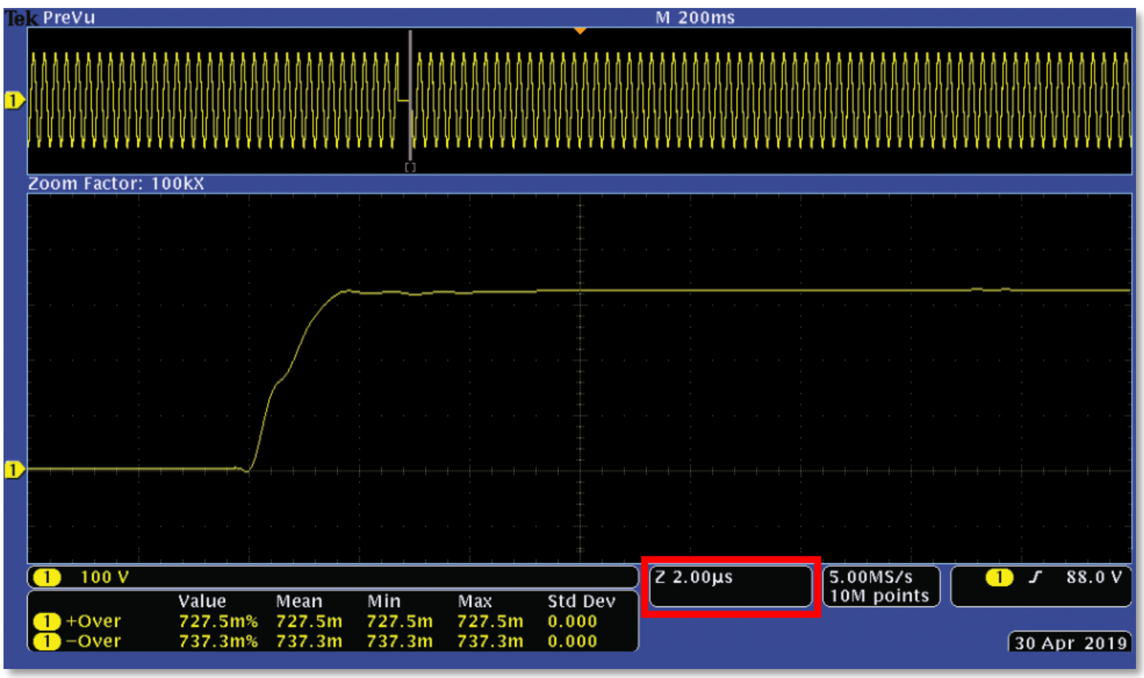


Figure 3: EPTS Voltage Rise Time at 90° = 2 µsec

5 Voltage Rise and Fall Times without the EPTS Option

When the AC source is used for Voltage Dips and Interruptions testing without an EPTS electronic switch, the power source must support a high voltage slew rate to test at 90° or 270° phase angles. While it may be possible to design a linear AC Source than can supports these high voltage slew rates, switch mode AC power sources generally do not. High speed linear AC source are prohibitively expensive, large and heavy, except at very low power levels that are not suitable for IEC 61000-4-11 testing.

5.1 For Single Phase EUTs

The AC power source can be used for pre-compliance testing in all cases. For single phase EUTs that require testing at 0° and/or 180° phase angles, full compliance testing is achieved, as any dips or interrupts starting from zero volt and lasting an integer number of periods do not require high voltage slew rates. : For testing EUTs at dips or interrupts starting at different phase angles, a fast switch like the EPTS will be required.

Note: At this time there are only a few medical electrical products that require testing at 90 and 270 degrees. Details are provided in the family of IEC 60601-1-x standards.

5.2 Three Phase EUTs

For three phase EUT testing, this situation is different as the start phase angles are referenced to phase A but phase B and C are 240° and 120° apart so the transition time for dips and interruptions executed on phase A at 0° or 180° are not an issue but on phases B and C, the voltage is not transitioning through zero volt at that moment in time. The figure below illustrates the case of phase B and C dropped at the 0° phase A reference point.

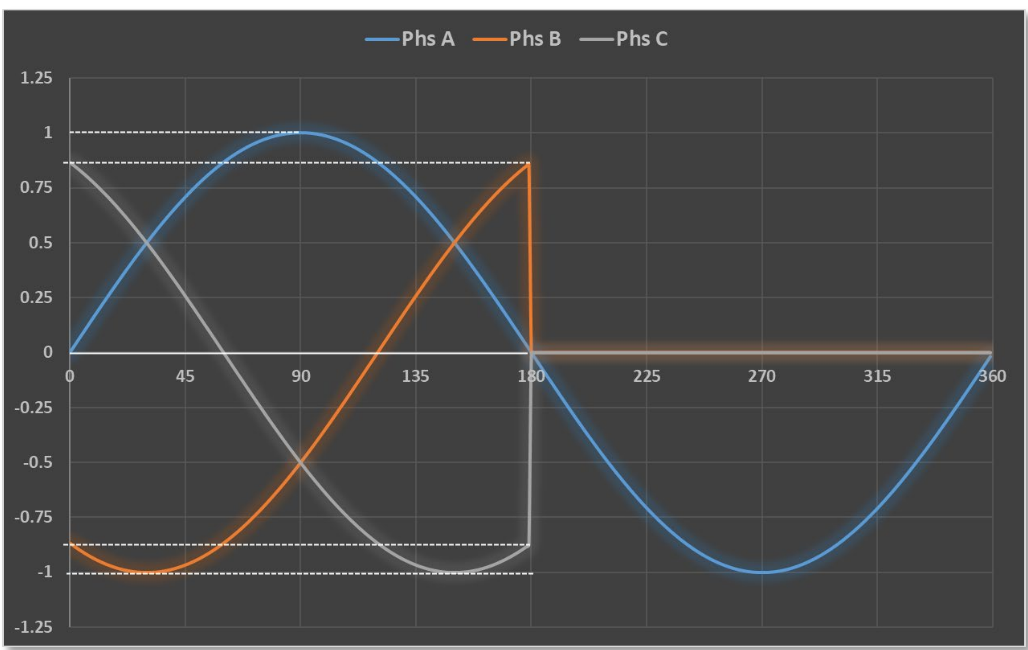


Figure 4: Three Phase EUT Voltage Interruption on Phases B & C

Clearly the voltage transitions on phases B and C occur at 120° and 240° which coincides with 0° on phase A. At these phase angles, the voltage waveform is at 85% of the absolute peak voltage so for a 230Vac RMS sinewave, the voltage levels for B and C change the following amount of voltage:

230Vrms * √2 * 0.85 = + and - 276Vpk

Assuming a 10% and 90% definition of voltage slew rate, the AC source voltage has to change (0.9 – 0.1) * 276V = 0.8 * 276V = 220.8V. Thus, to meet the less than 5 µsec transient time required, the AC source must slew the voltage at a rate of 221V / 5E-6 = 41.2 V/ µsec.

Most PWM switch mode AC power sources support voltage slew rates of a few Volts / µsec so are not qualified for full compliance testing of three phase EUT's, although they can be used for pre-compliance testing.

6 Summary

For most product categories that are tested using voltage interruptions at 0° and 180°, the rise and fall time requirement of the AC power source is not a consideration. For those product categories that have to be tested using 90° and/or 270° phase angles voltage interruptions, the AC power source most likely will not meet the required rise and fall time for the voltage. In these situations, the use of the EPTS electronic switch is recommended unless testing is done for pre-compliance purposes only.

In order to fully meet the requirements of IEC 61000-4-11 clause 6.1.2 however, the use of an EPTS would be required. Clause 6.1.2 requires verification of rise and fall times at 90 and 270 deg with a 100 Ohm resistive load for a fully compliant dips/interrupt test generator.

This approach is particularly useful in Asia and Europe. EPTS units are available in single or three phase version and up to 100Arms per phase. See https://pacificpower.com/products/ects2-series/#products-ects2-models for available models. The EPTS units also alleviates the need to meet the peak inrush requirements for IEC61000-4-11 and IEC61000-4-34. See separate Application note "IEC 61000-4-11 & 34 Testing and AC Source Peak Current".

For USA applications, a second AC source or AC Generator is needed to test with 50Hz, 230V_{LN} single or three phase nominal voltage.

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