APPLICATION NOTE #103

IEC 1000-4-11 Test & Measurement Techniques to Verify Immunity from Voltage Dips, Interruptions & Variations

The Standard

The IEC1000-4-11 standard concerns testing and measurement techniques that verify the immunity of electrical (and electronic) products from "voltage dips, short interruptions, and voltage variations". Although the standard is European, it is being used as a basis for internal company design verification testing throughout the world.

The need for a "standard" for this type of testing is clear. There are many ways to test a product to verify immunity from line variations, and some form of standardization, for comparison purposes, is desirable. However, IEC 1000-4-11 leaves many options available, and does not absolutely specify which tests should apply to a particular type of product.

The standard also seeks to specify the parametric requirements of an AC source suitable for performing the specified tests. Generally, these requirements go beyond what is necessary to perform the specified tests on a particular product. For example, it is neither necessary nor cost effective to have an in-rush current capability significantly greater than that needed by the product to be tested.

In this application note we will explain the tests specified in the standard and draw conclusions concerning the capabilities of suitable AC power sources to perform those tests.

Generally, throughout this document, comments in italics are commentary on the spec. Normal type is either a direct quote from the spec or a precise explanation

Test Levels

Voltages specified are the rated voltage of the equipment (Ut). If the equipment to be tested has a specified input voltage range, then testing should be performed at the lower and upper limits of the voltage ranges specified. However, in practice it is only necessary to perform the tests at the lowest specified input voltage, since all the tests concern a reduction or interruption of supply voltage.

As a further guide to the test parameters to be applied to the equipment under test, this standard advises the typical number of occurrences per annum (in Europe) for various durations of line voltage reduction or interruption (see Fig. 1).

Depth	Duration			
(Voltage Reduction)	10 to 100 ms	100 to 500 ms	500 ms to 1 s	1 s to 3 s
10 to < 30 %	61	66	12	6
30 to < 60 %	8	36	4	1
60 to < 100 %	2	17	3	2
100 %	0	12	24	5

Fig. 1 : Number of typical Line Disturbances annually, in Europe.

Tests for Voltage Dips and Short Interruptions

All changes in the test voltage must be abrupt, and not slewed. The test can start and stop at any phase angle of the line voltage, and should not be contrived to occur at the best case condition. Tests are specified at 0%, 40% and 70% of the rated input voltage (Ut) of the product under test. This is a reduction in test voltage (Ut) of 100%, 60%, and 30%.

The duration of the test (reduction in voltage) is specified in periods of the supply voltage. These range from 0.5 to 50 cycles, or any duration up to 3000 cycles, although the standard states that dips and interruptions of greater than 50 cycles are not common.

The following table of Preferred Test Levels and Durations appears in the standard.

Test Level % of Ut	Voltage Dip/Interruption % Ut	Duration (Periods)
0	100	0.5*
		1
40	60	5
		10
70	30	25
		50
		X

Fig. 2: Preferred Test Levels and Durations

(*) For 0.5 Period, the test shall be made in positive and negative polarity, i.e. starting at 0^{o} and 180^{o} respectively.

Notes:

1) One or more of the above test levels and durations may be chosen.
Particular test levels and durations are not specified.
2) If the EUT (Equipment Under Test) is tested for voltage dips of 100%, it is generally unnecessary to test for other levels for the same durations. However, for some cases (safeguard systems or electromechanical devices) this is not true. The product specification or product committee shall give an indication of the applicability of this note.
Again, 100% dips (or interruptions) are not actually specified. This is defined in the Product Specification or specified by the "Product Committee". (See "The Product Committee" & Product Specifications following this section)
3) "X" is an open duration which can be given in a product specification. Utilities in Europe have measured dips and short interruptions between 0.5 and 3,000 periods, but durations of less than 50 periods are most common.
4) Any duration may apply to any test level.
Note again that the combination of items 1) and 4) leaves a great deal of speculation to the company or authority making the test.

To answer the question of whether a particular power source can be used for IEC 1000-4-11 applications demands that the user first specify which of the 1000-4-11 tests they wish to apply to their product.

The Product Committee

Often a group of manufacturers of the same or similar products will get together to decide which tests should be run on a particular group of products; i.e., appliances such as Stereo Systems.

That industry group will decide what tests are necessary, taking into consideration the environment in which the products will be used, and the level of product sophistication. For a manufacturer of Stereo Systems to claim that their Systems meet IEC 1000-4-11, a series of tests, as defined by the industry group, must be run and the results must be acceptable (again as defined by the industry group or "Product Committee").

Product Specifications

If a Product committee does not dictate which tests should be performed, then it is up to the manufacturer to define the tests in a product specification. To ensure integrity, tests should be defined according to market and user requirement, not according to which of the many combinations of tests the unit actually passed.

Note: The voltage decreases to 70% for 10 periods. Steps are at zero crossing

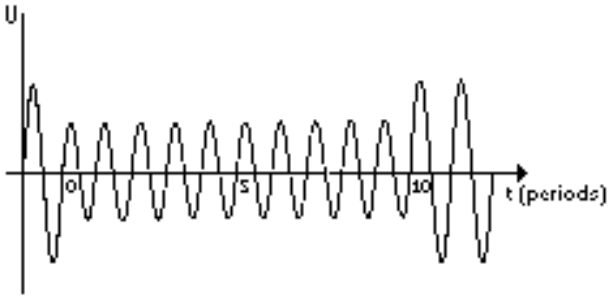

Fig. 3: Typical Voltage dips test.

Voltage Variations (optional)

These tests consider defined transitions between the rated voltage (Ut) and a changed voltage. As noted, they are optional and not required (unless defined by the Product Committee). This section of the standard defines simulated voltage changes that take place over a relatively short period, and may occur due to change of load, or stored energy in the local power network.

The preferred voltages, slew rates, and durations are given in Fig. 4. The rate of change of voltage should be constant; however, the voltage may be stepped. The steps should occur at the zero crossings, and shall not be greater than 10% of Ut. Steps under 1% of Ut are considered as a constant change of voltage.

Note: Figure 5 shows a typical voltage variations sequence.

Voltage Test Level	Time for Decreasing V	Time at Reduced V	Time for Increasing V
40 % of Ut	2s ± 20 %	1s ± 20 %	2s ± 20 %
0 % of Ut	2s ± 20 %	1s ± 20 %	2s ± 20 %
	x	x	x

Fig. 4: Timing of short term supply voltage variations.

Note: X represents an open set of durations that can be given in the product specifications.
Again, not only is this test optional, but it leaves a great deal of leeway to the company or authority performing the test.

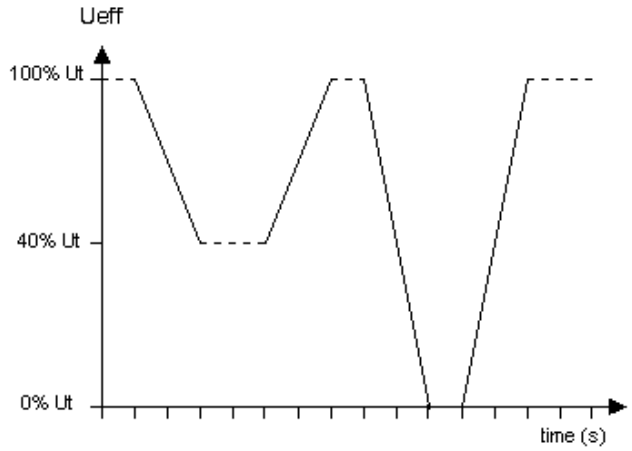

Fig. 5: Typical Voltage variations test sequence.

Test Conditions for Performing IEC 1000-4-11 Tests

The following section describes the recommended test plan and test report.

1. Prepare a test plan specifying the following:
   a) The type designation of the EUT.
   b) Pertinent information concerning the connections, (plugs terminals etc.) and corresponding cables and peripherals.
   c) Input power port of the equipment used.
   d) Operational modes of the EUT.
   e) Performance criteria.
   f) Operational modes of the equipment.
   g) Description of the test set-up.

Record any degradation of performance for each test. The monitoring equipment should be capable of displaying the status of the operational mode of the EUT during and after the tests. After each group of tests, a full functional check shall be performed.

2. The climatic conditions should be within the following ranges:
   Temperature: 15 - 35° C
   Relative humidity: 25 - 75 %
   Barometric pressure: 86 - 106 kPa

3. Electromagnetic conditions:
   The electromagnetic conditions shall be such to guarantee the correct operation of the EUT in order not to influence the test results.

4. Execution
   During the tests the supply voltage for testing is monitored to an accuracy of 2%. The zero crossing control of the test generator must have an accuracy of ±10°.
   a) Voltage dips and short interruptions
      The EUT shall be tested for each selected combination of test interval and duration with a sequence of 3 dips /interruptions with 10 seconds minimum interval between each test event. Each representative mode of operation shall be tested.
      Abrupt changes in supply voltage should occur at zero crossings, and at additional angles considered critical by product committees or individual product specifications.
      For 3-phase systems, phase by phase test is preferred. In certain cases (3-phase meters and 3-phase supply equipment) all three phases must be simultaneously tested. When dips and interruptions are applied simultaneously to all three phases, the zero crossing condition will be fulfilled on only one phase.
   b) Voltage variations (optional)
      The EUT should be tested to each of the specified voltage variations, three times at 10 second intervals for the most representative modes of operation.

5. Test results and test report
   Basically the test results should be noted, and classified as follows:

   a) Normal performance within specification limits.
   b) Temporary degradation or loss of function or performance which is self-recoverable.
   c) Temporary degradation or loss of function or performance which requires operator intervention or system reset.
   d) Degradation or loss of function which is not recoverable due to damage of equipment (components) or software, or loss of data.

   The EUT shall not become dangerous or unsafe as the result of the application of the tests defined in the standard.

The standard does not define PASS or FAIL criteria. However, category a) is a clear PASS, b) is usually also interpreted as a PASS. Even c) can be defined as a PASS , if that is the way the performance of the product to these non-standard line input conditions is defined. However, it would be difficult to think of any condition where category d) could be considered as a PASS.

Test Generator (AC Supply Source) considerations:

Specifications

Output Voltage: As required, ±5%

Change with load (load regulation requirement at various output levels):

100% output, 0 to 16 A rms.	< 5 %
70% output, 0 to 23 A rms.	< 7 %
40% output, 0 to 40 A rms.	< 10 %

Output Current Capability:

16 A rms. at 100% of Ut (per phase)
23 A rms. at 70% of Ut
40 A rms. at 40% of Ut

(These are the requirements from the Standard. It is not necessary to provide this current capability if it is not required by the EUT)

Peak Inrush Current Drive Capability:

(not required for voltage variation tests)
Must not be limited by the generator. However, need not exceed 500A for 220-240V, and 250A for 100-120V.
(see comment for Output Current)
The inrush current of the EUT should be less than 70% of that available from the AC source.

Inrush current can be measured with a current transformer and storage oscilloscope or suitable power analyzer. Worst case conditions are usually at 90° and 270°.

Overshoot/Undershoot:

Loaded with 100 ohms < 5 %

Voltage Rise/Fall Time, Abrupt Change:

Loaded with 100 ohms 1 to 5 µs

(The specification here is 1 to 5 ms; however, the voltage variation spec.'s are over 1 or 2 seconds, and the dips and short interruption tests should occur at zero crossings, making the rise/fall time relatively unimportant if other spec requirements are met.)

Phase Shifting: 0 to 360 Degrees

Phase Relationship of Voltage Dips & Interruptions with Power Frequency: ±10°

(Since 10° is 560 ms at 50 Hz, this also presents the question of why the rise time specification needs to be < 5 ms)

Output Impedance

Predominately resistive
Must remain low even during transitions

Note: *Certain of the generator characteristics are not absolutely required for any of the tests, e.g. peak inrush drive capability (if not required by the EUT) and rise/fall time*.

California Instruments AC sources generally meet or exceed the requirements for IEC 1000-4-11 testing applications. However, the source must be sized so that the EUT can draw sufficient current at reduced voltage. Also, some sources require the -ODS option to perform 0.5 cycle (and odd multiples of 0.5 cycles) dropout tests.

To determine the correct AC source for performing IEC 1000-4-11 tests requires the following essential information:

A) Steady state rms. current at the EUT at nominal input voltage.
B) Peak in-rush current at nominal input voltage, and duration of the in-rush current.
C) A definition of which of the many IEC 1000-4-11 tests will be performed.
D) A definition of which of the many IEC 1000-4-11 tests will be performed and other information such as load current at 70% and/or 40% of nominal input voltage (it is wise to check the equipment rather than extrapolate. Many devices will shut off around 70% of nominal input voltage; therefore, the load current at 40% is probably zero).

With this essential information, a California Instruments Applications Engineer can determine the best AC power source for the application.

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