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APPLICATION NOTE - 027

IEC61000-4-11:2001 Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

The IEC61000-4-11:2001 standard replaced the previous standard, published in 1994. The 2001 version added test values and durations for different environment classes, as well as including three phase test sequences.

Overview of IEC61000-4-11

Any device connected to a "low voltage" supply network should reasonably expect to be subjected to dips, interruptions, and voltage variations from the low voltage source. The "low voltage" source we refer to is the voltage supply at the consumers socket outlet, whether it be a domestic (230V EU / 100V USA/Japan) or Industrial three phase supply.

The IEC61000-4-11 standard describes a series of test waveforms, subjecting electrical and electronic equipment to the same specified waveform sequences reflecting common disturbances to the low voltage line.

IEC61000-4-11 applies to equipment not exceeding a 16A per phase rating, for connection to 50/60Hz networks. IEC61000-4-11 does not cover equipment that is connected to 400Hz networks (such as within the aerospace industry).

Voltage dips and short interruptions are often caused by faults in the network, these faults are primarily short circuits of some description or sudden changes in the load on the network. Variations are a slightly different phenomena, caused by continual variations of the load on the network.

In reality, these variations are random, occurring at random times and of random amplitude. For the purpose of laboratory testing in a controlled environment, IEC61000-4-11 specified certain deviations from the rated voltage for specific intervals. The variations and intervals are intended to be representative of disturbances commonly found on the network. If a device can continue normal operation when subjected to the specified voltage dips, interruptions and variations in IEC61000-4-11 then it is expected that the same will be the case when connected to a real-life supply network.

What is Immunity?

Immunity is the ability of a device, equipment, or entire system to continue to perform without degradation to its performance in the presence of an electromagnetic disturbance. An example of this is the ability of a television receiver to maintain normal operation during a "half cycle drop-out" event on the voltage supply.

What is a disturbance?

A disturbance in this standard is determined as a voltage dip, short interruption, or variation in the supply. This standard defines various phenomena against which the equipment is tested.

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Voltage Dips

A voltage dip is a sudden reduction in voltage at a particular point of an electricity supply system. The supply voltage dips below a specified threshold for a brief interval before restoration to its original level.

An example sequence of Vrms values could be as follows;

Signal: 230Vrms, 50Hz, Sinewave

Dip Voltage Level: -10% , 217Vrms

Sequence:

Cycles	Voltage Level (Vrms)
100	230
1	217
100	230

In this example, the output waveform maintains 230Vrms for 2 seconds (100 cycles at 50Hz), drops to 217Vrms for 1 cycle (20ms) and returns to the original 230Vrms amplitude for the final 2 seconds. The total sequence time is 2.020 seconds.

The causes of voltage dips on the supply network is a temporary short circuit or other extreme current increase on the system or on an installation connected to that system.

Voltage dips are two dimensional, in that both voltage amplitude and the time (duration) of the dip are considered.

Short Interruptions

A short interruption according to IEC61000-4-11 is a sudden reduction in supply voltage on all phases at a particular point of a supply system below a specified interruption threshold. After a brief interval the voltage level is restored to its original value. Similar to voltage dips, short interruptions are commonly caused by the occurrence and termination of short circuits on the system or installations connected to it.

Residual Voltage (of Voltage dip)

Residual voltage is the minimum r.m.s. voltage recorded during the voltage dip or short interruption. Expression of the r.m.s. value can be in Vrms or percentage per unit value relative to the reference voltage.

Malfunction

The IEC61000-4-11 standard pass/fail's the device under test by determination if the device malfunctions during the voltage disturbance. A malfunction is determined as a fail and is defined as the termination of the ability of equipment to carry out their intended functions, or the execution of unintended functions during/after the disturbance.

Which tests apply to a particular product?

The IEC61000-4-11 standard states that it is the product committee's responsibility to determine which phenomena in this standard are relevant to a particular product.

Voltage Test Levels

All tests in the IEC61000-4-11 standard use the rated voltage of the equipment under test (U_T) as a basis for voltage test level specification.

If the equipment under test has a rated range of input voltages the following rules apply;

- If the upper voltage range does not exceed 20% of the lower voltage range, a single voltage point within the range of input voltages can be selected as the test voltage for the tests within IEC61000-4-11.
- If the voltage range exceed this 20% limit, the upper and lower voltages of the given range shall be used throughout the test.
- If guidance is required for test levels and test durations, this is given in IEC61000-2-8.
- Guidance for determining the class of a product is given in IEC61000-2-4.

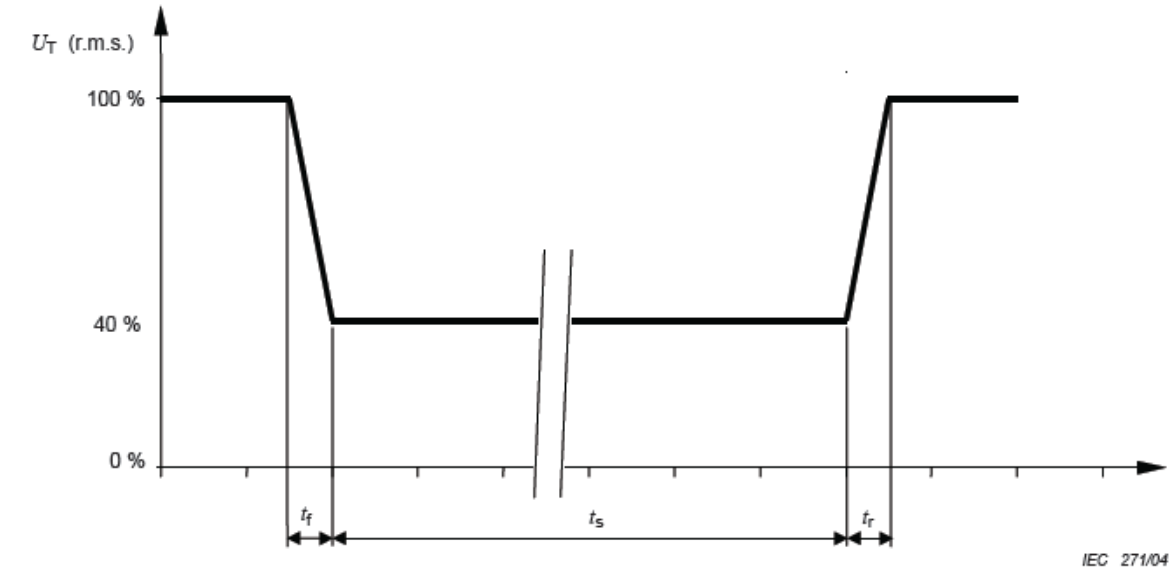
Voltage Dips - Test Levels and Durations

Section 5.1 of IEC61000-4-11 describes the requirements for voltage change between the rated voltage (U_T) and the magnitude during the voltage dip. The magnitude of the dips are given as a % of U_T and are given as follows in table 1 of IEC61000-4-11;

Voltage Dip Test Levels (%U_T)

Class	Test Level and Durations for voltage dips (ts) (50Hz/60Hz)				
Class 1	Case-by-case according to the equipment requirements				
Class 2	0% during 0.5 cycle	0% during 1 cycle	70% during 25/30[a] cycles		
Class 4	0% during 0.5 cycle	0% during 1 cycle	40% during 10/12[a] cycles	70% during 25/30[a] cycles	80% during 250/300[a] cycles
Class X	X	X	X	X	X

IEC61000-4-11, table 1



Key
t_r Voltage rising time
t_f Voltage fall time
t_s Time at reduced voltage

Figure 1 - Voltage Dip - 40% voltage dip r.m.s. graph

Figure 1 illustrates a 40% dip voltage variation, found in table 1 - class 4.

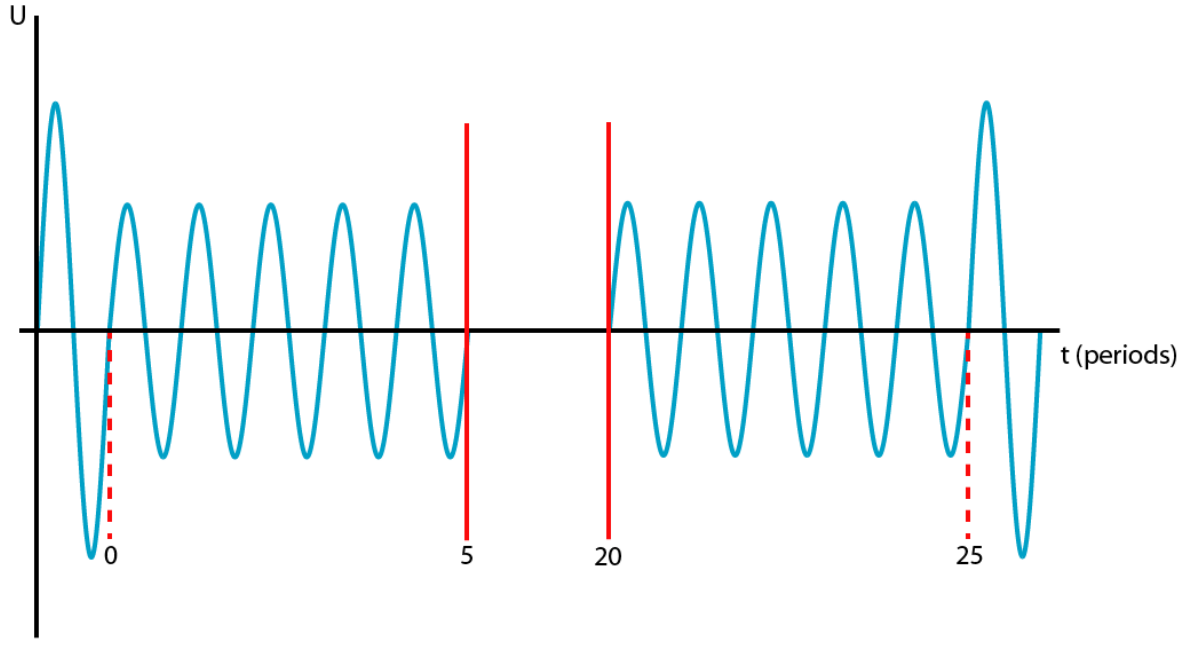


Figure 2 - Voltage Dip example - 70% for 25 cycles

Figure 2 illustrates an example from table 1, class 2 of IEC61000-4-11.

Class X must be defined by the product committee, for any equipment that is to be connected to the public network directly or indirectly the test levels must be equal to or greater than the test levels of class 2.

[a] 25/30 cycles relates to - 25 cycles at 50Hz and 30 cycles at 60Hz, depending upon whether the device is being tested at which frequency.

It is important to note that IEC61000-4-11 states in section 5.1 that the voltage step (start and stop) can occur at any phase angle on the supplied voltage. Newtons4th step the voltage up and down at the zero crossing point. This ensures compliance with the defined "time for increasing voltage" and "time for decreasing voltage" in figure 3 and table 4 of IEC61000-4-11.

Table 1 describes test levels that are rather severe in nature, and although they are representative of real world voltage dips they do not guarantee immunity to all dips. More severe dips such as 0% for 1 second and balanced three phase dips can be considered by the product committee.

Voltage Interruptions - Test Levels and Durations

The preferred test levels for short interruptions are specified in table 2, shown below. The test levels specified in table 1 and 2 are taken from information provided in IEC61000-2-8.

Class[a]	Test Level and Durations for voltage dips (ts) (50Hz/60Hz)
Class 1	Case-by-case according to the equipment requirements
Class 2	0% during 250/300 cycles[b]
Class 3	0% during 250/300 cycles[b]
Class X[b]	X

IEC61000-4-11, table 2

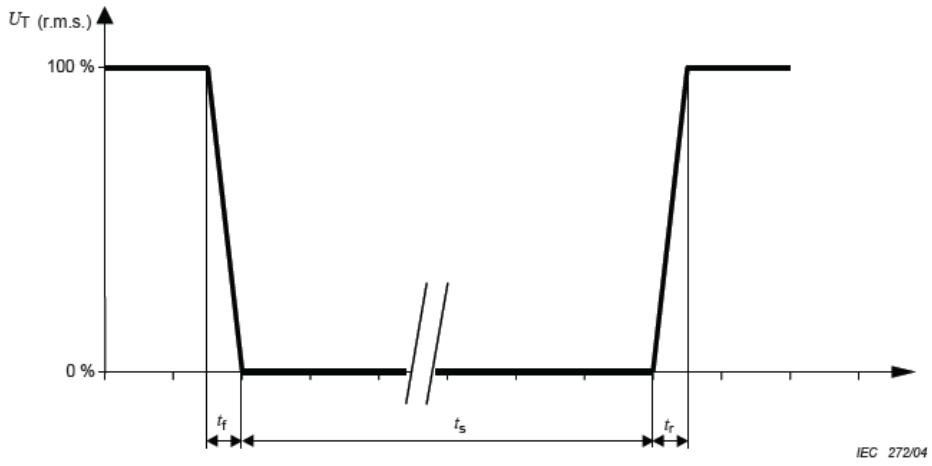
a Classes as per IEC61000-2-4

b 250/300 cycles refers to 250 cycles for 50Hz tests and 300 cycles for 60Hz tests.

The standard states that supply interruptions of 20% or lower can be considered a total interruption of the supply.

When testing a product with a mains transformer at the input, product committees should be aware of the effects of inrush currents. Such products can experience 10 to 40 times the rated current due to magnetic flux saturation of the core after a voltage dip.

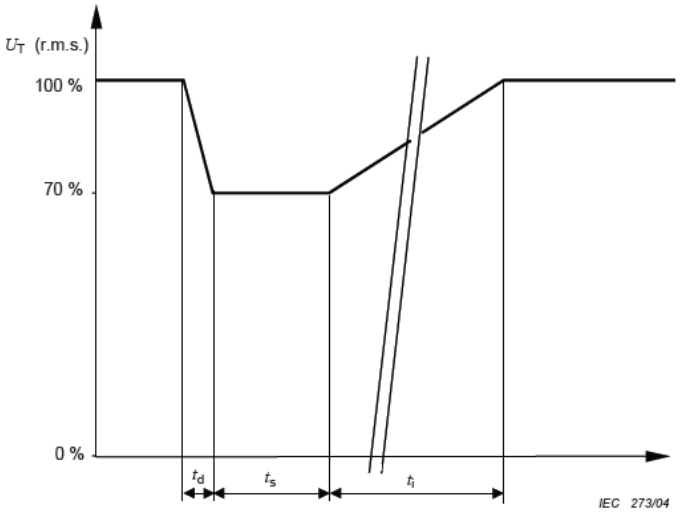
Figure 3 illustrates an example of a short interruption test, the test durations for this test can be found in table 1.



Key
t_r Voltage rising time
t_f Voltage fall time
t_s Time at reduced voltage

Voltage variations - Optional test

An optional test is specified in IEC61000-4-11 which details the transition between the rated voltage (U_T) and the changed voltage. Figure 3 below illustrate the voltage variation, in which the voltage change takes place over a short period.



Key
t_d Time for decreasing voltage
t_i Time for increasing voltage
t_s Time at reduced voltage

Figure 3 - Voltage variation

In the field, such a variation is likely to take place due to a change of load on the network. Whereas "dips and interruptions" generally occur due to faults on the network.

Table 3 in IEC61000-4-11 details the preferred durations for voltage changes and the time for which the reduced voltages need to be maintained.

As per IEC61000-4-11, the N4L AC Power sources (N4A range) step the voltage at zero crossing and the steps are no larger than 10% of U_T. Steps of this nature are considered to be constant rates of change.

Voltage test level	Time for decreasing voltage (t_d)	Time at reduced voltage (t_s)	Time for increasing voltage (t_i) (50Hz/650Hz)
70%	Abrupt	1 Cycle	25/30[b] Cycles
X[a]	X[a]	X[a]	X[a]

IEC61000-4-11, table 3

[a] To be defined by product committee

[b] 25/30 Cycles means 25 Cycles at 50Hz and 30 Cycles at 60Hz

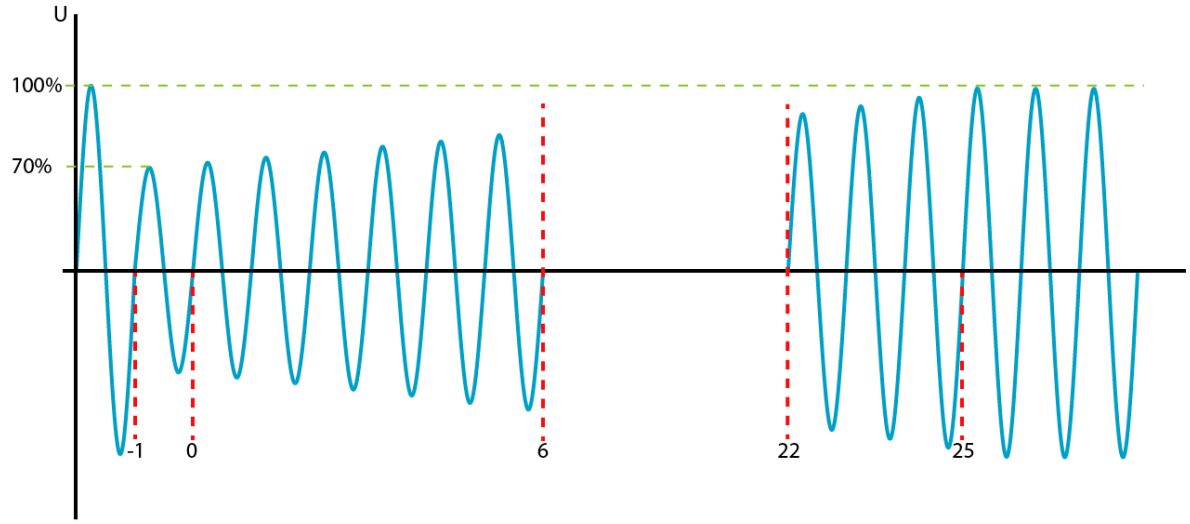


Figure 4 - Example Voltage variation waveform

Figure 4 illustrates a voltage variation waveform as per table 3 of IEC61000-4-11. The Vrms is abruptly changed to 70% of the reference voltage for 1 cycle, the voltage then recovers at a constant rate for 25 cycles until it recovers to 100%.

Test Generator (AC Power Source)

Newtons4th have developed an AC Power Source that is capable of all of the specified test waveform sequences as detailed in IEC61000-4-11. The AC power source should not inject disturbances into the power supply network as this may influence test results.

If the generator is able to create voltage dips of equal or more severe characteristics (with respect to amplitude and duration) then this is permitted by the standard.

Table 4 in the IEC61000-4-11 standard defines the characteristics of the AC power source, at its most severe table 4 specifies 5% voltage regulation when a load of up to 40% output is applied from 0A to 40A. The N4A AC power sources meet this requirement.

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Verifying the characteristics of the AC Power Source for Voltage Dips and Short Interruptions

Any test generator that is used for complaint IEC61000-4-11 testing must comply to the specified requirements set out in the IEC61000-4-11 standard.

Voltage level accuracy (no load at output of generator)

Voltage Level	IEC61000-4-1 Requirement (Section 6.1.2)	Accuracy of N4A Power Source
100% - 230V, 120V etc	5%	0.5%
80%	5%	0.5%
70%	5%	0.5%
40%	5%	0.5%

The N4A AC(+DC) Power Sources guarantee a voltage level accuracy of 0.5%.

Voltage regulation (nominal load current of generator)

Voltage Level	IEC61000-4-1 Requirement (Section 6.1.2)	Accuracy of N4A Power Source
100% - 230V, 120V etc	5%	0.5%
80%	5%	0.5%
70%	5%	0.5%
40%	5%	0.5%

The N4A guarantees a voltage change with a load applied to the generator of better than 0.5%, meeting the requirements of IEC61000-4-11.

Output Current Capability

IEC61000-4-11 specifies the following output current requirements;

Output Current	Rated Voltage	Duration	N4A06 (plus all higher power N4A models) Specification
16A	100%	Continuous	Continuous
20A	80%	5 seconds	Continuous
23A	70%	3 seconds	Continuous
40A	40%	3	Continuous

The N4A06 series AC Power Source offers a great advantage over other amplifiers on the market as the 6kVA (20A continuous output current) model is able to deliver 2x continuous current for 3 seconds meeting all requirements of the IEC61000-4-11 standard. The continuous current rating of the N4A06 is 20A, therefore this amplifier meets all requirements stated above.

Peak Inrush Capability

The requirements of peak inrush capability of the generator for compliance to IEC61000-4-11 is stated as follows;

U_T (Nominal Line Voltage)	Peak Capability of Generator
250V ~ 600V	1000A
200V ~ 240V	500A
100V ~ 120V	250A

The N4A06 satisfies all the above requirements up to 1000A peak inrush capability.

Voltage Rise and Fall Times

IEC61000-4-11 specifies rise and fall time requirements of 1uS to 5uS (IEC61000-4-11 - table 4.) This requirement has caused a lot of confusion in the test and measurement industry, so much so that the IEC released an interpretation note that explains when this is required. Interpretation note 77A/720/DC explains that rise and fall times of 1uS to 5uS are only possible in a power source featuring a switched multi-tap transformer connected to the output. This requirement is only for generator verification and is not required by test labs performing IEC61000-4-11 compliance testing. The reason for this is when testing a real product, a laboratory will perform test routines that modulate the Vrms value of the waveform at the zero crossing point, as specified in IEC61000-4-11. Section 5.1 of IEC61000-4-11 states that the step can start or stop at any phase angle on the mains voltage. It is therefore convenient to start the change at zero crossing, where there is no requirement for a high slew rate of 1uS ~ 5uS, therefore this requirement is not required for complaint tests to be made of a real DUT in the field.

Phase Shifting - The generator must be capable of phase shifting from 0~360°, the phase relationship of the voltage dips and interruptions with the power frequency must be less than +/- 10°.

Furthermore, zero crossing control of the generator must be +/- 10°

Parameter	Requirement	N4A Performance
Phase shifting range	0~360°	0~360°
Phase relationship with voltage dips and interruptions with power frequency	+/- 10°	0.5°
Zero crossing control of the generators	+/- 10°	0.5°

Output Impedance - The output impedance of the power source should be predominantly resistive and less than 0.4Ω and j0.25Ω. This impedance is far greater than the output impedance of the N4A AC Power Sources. It is worth noting that this impedance is equal to the reference impedance specified in IEC61000-4-15 for flicker testing.

Frequency Accuracy

The requirements of the IEC61000-4-11 standard are +/-2%, the N4A series of AC Power Sources offer xxx% frequency accuracy.

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References:

- International Electrotechnical Vocabulary. (1990). Electromagnetic Compatibility – Chapter 161, IEC 60050-161:1990. International Electrotechnical Vocabulary.
- International Electrotechnical Commission. (2004). Electromagnetic compatibility (EMC) – Part 4-11: Testing and Measurement Techniques - Voltage dips, short interruptions and voltage variations immunity tests. International Electrotechnical Commission.