Insights and best practice

EMC COMPLIANCE KNOW-HOW

TECHNICAL NOTE 0114

AC VOLTAGE
DIPS, DROPS, AND VARIATIONS

Overview

Electrical equipment can be affected by voltage variations on their power supply lines. Voltage dips and short interruptions occur due to faults in public private networks or sudden changes of large loads; whereas voltage variations are caused by continuously varying loads connected to the network. Whether these variations are abrupt or gradual, the normal operation of consumer and industrial electronic and electrical devices and equipment can be adversely affected.

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AMETEK®
COMPLIANCE TEST SOLUTIONS

In order to evaluate whether a device can withstand these fluctuations, standards have been created to define how to test devices' immunity to power line voltage variations. Among them are IEC 61000-4-11, which describes testing and measurement techniques for immunity to voltage dips, short interruptions, and voltage variations for equipment with input current up to 16 A per phase; and IEC 61000-4-34 which covers testing for mains current of greater than 16 A per phase. These standards are for 50 and 60 Hz, with 400 Hz specifically excluded from both standards.

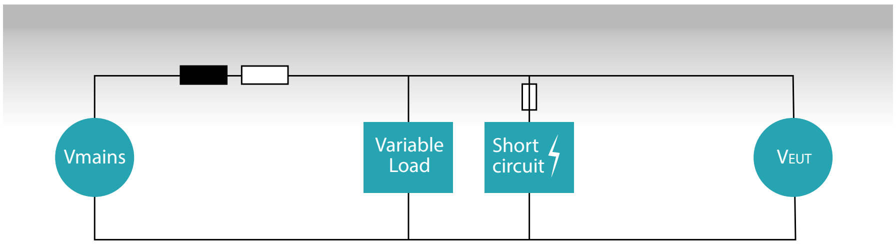


Figure 1

Simplified model for voltage dips, interruptions and variations

In order to test the three phenomena in 61000-4-11/34, typically an AC power source such as the AMETEK CTS NetWave or ACS 503N series, a tapped or variable transformer, and a switching device such as the AMETEK CTS compact NX, NSG 3000A, or PFS 503N series is useeeeee

ACS 503N SERIES
3-phase AC voltage source

NETWAVE
Programmable AC/DC source

COMPACT NX5
Multi test generator for transients

NSG 3040A
Multifunction for CE testing

PFS 503N SERIES
Power fail simulator

Voltage Dips

Voltage dip is commonly defined as any low voltage event between 10% and 90% of the nominal RMS voltage lasting between 0.5 and 300 cycles. On the other hand, voltage swells (which are not so common) do not normally disrupt sensitive load but, can cause harm to equipment. Voltage dips can be caused by natural events (e.g., trees falling on power lines or lightning striking lines or transformers), utility activities (e.g., routine switching operations or human error), or customer activities. Because of the short duration of these dips, residential customers (such as described by Class 2 in Table 1) rarely notice.

Class[a]	Test levels and durations for voltage dips (t_s) (50 / 60 Hz)				
Class 1	Case-by-case according to equipment requirements				
Class 2	0% during ½ cycle	0% during 1 cycle	70% during 25/30[c] cycles		
Class 3	0% during ½ cycle	0% during 1 cycle	40% during 10/12[c] cycles	0% during 25/30[c] cycles	0% during 250/300[c] cycles
Class X[b]	X	X	X	X	X

[a] Classes as per IEC 61000-2-4; see Annex B

[b] To be defined by product committee. For connected directly or indirectly to the public network, the levels shall not be less severe than class 2

[c] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test"

Table 1

Preferred Test Levels and Durations for Voltage Dips

Class 1: Applies to equipment that is very sensitive to disturbances such as lab instruments, automation controls, and some computers. Class 1 environments normally contain equipment which requires protection by such apparatus as uninterruptible power supplies (UPS), filters, or surge suppressers.

Class 2: Applies to equipment connected to public networks

Class 3: Applies only to equipment in industrial environments. It has higher compatibility levels than those of class 2 for some disturbance phenomena. For instance, this class should be considered when any of the following conditions are met:

- – a major part of the load is fed through converters;
- – welding machines are present;
- – large motors are frequently started;
- – loads vary rapidly.

The supply to highly disturbing loads, such as arc-furnaces and large converters which are generally supplied from a segregated bus-bar.

Class X: Frequently has disturbance levels in excess of class 3 (harsh environment). In such special situations, the compatibility levels should be agreed upon prior to testing.

Voltage Dip Test Setup

The EUT must be tested for each selected combination of test level and duration with a sequence of three dips / interruptions with intervals of 10s minimum between each test event (Figure 2). Depending on the class of the EUT, the voltage will be dipped to 80%, 70%, and 40% of the mains RMS voltage. Each representative mode of operation must be tested. For voltage dips, changes in supply voltage must occur at zero crossings of the voltage, and at additional angles considered critical by product committees or product specifications, preferably selected from 45°, 90°, 135°, 180°, 225°, 270°, and 315° on each phase.

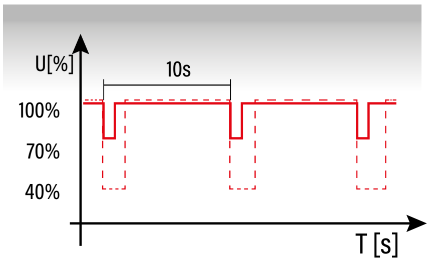


Figure 2

Dips Timing

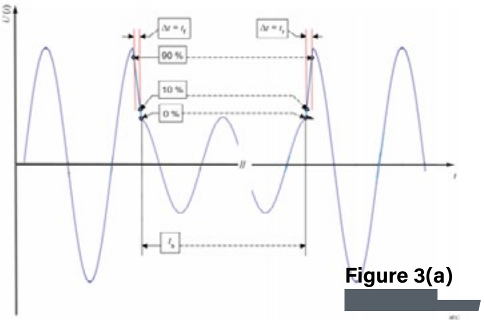
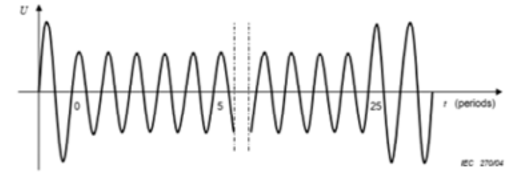


Figure 3(a)

Timing diagram for dip to 40%



NOTE The voltage decreases to 70 % for 25 periods. Step at zero crossing.

Figure 3(b)

Waveform diagram for dip to 70%

For voltage dips testing of three-phase systems with neutral, each individual voltage (phase-to-neutral and phase-to-phase) must be tested, one at a time, or six different series of tests. For the voltage dips test of three-phase systems without neutral, each phase-to-phase voltage shall be tested, one at a time, or three different series of tests.

If the mains voltage equals the EUT voltage, test setups like Figure 4 and Figure 5 would provide the necessary test parameters.

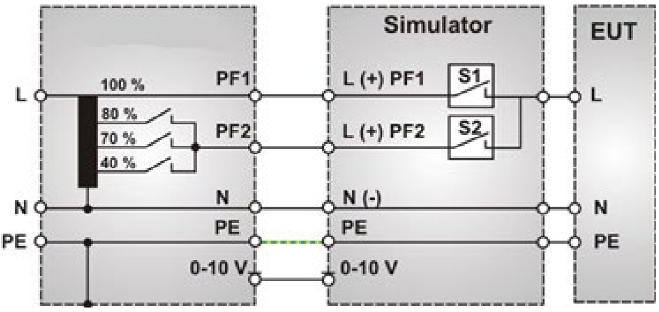


Figure 4

Voltage dip setup for single-phase EUT with same mains voltage as test lab using multi-tapped transformer

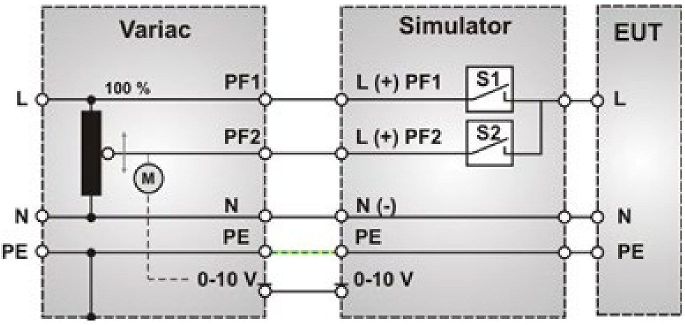


Figure 5

Voltage dip setup for single-phase EUT with same mains voltage as test lab using variable transformer

In Figure 4, the step transformer generates the dip voltages present at PF2 and the compact NX p switches between public network voltage (PF1) and the dip voltage (PF2). In a three-phase system a three-phase unit such as the PFS 503N would supply the required switching times. In Figure 5 a variable transformer is used to generate the dip voltage at PF2.

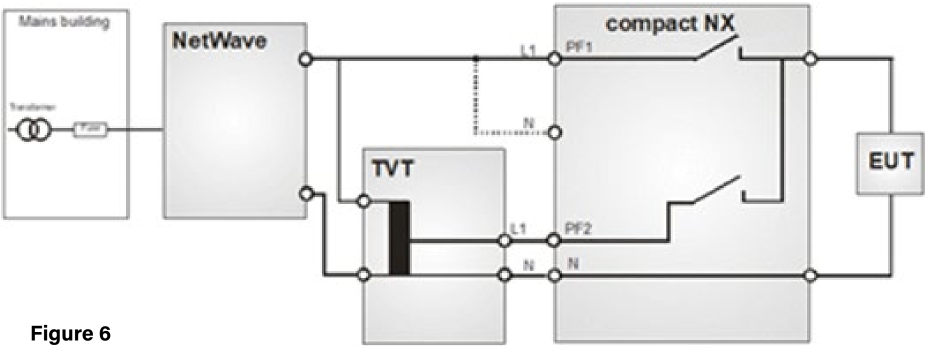


Figure 6

Voltage dip setup for single-phase EUT with different mains voltage as test lab

If the EUT needs to be tested to a voltage/frequency configuration that is different from the lab's mains supply, a configuration similar to Figure 6 can be implemented. In Figure 6, the NetWave AC Source simulates the mains public network by generating the necessary AC voltage and frequency for the EUT, and the transformer represented by the TVT symbol creates the dip voltage from the output of the AC source and the compact NX switches between the two voltages present at PF1 and PF2. The transformer can be either a multi-tapped or variable (variac).

Voltage Interruption (Drop)
Momentary voltage interruption is any low-voltage event of less than 10 percent of the nominal RMS voltage lasting for 5 seconds.

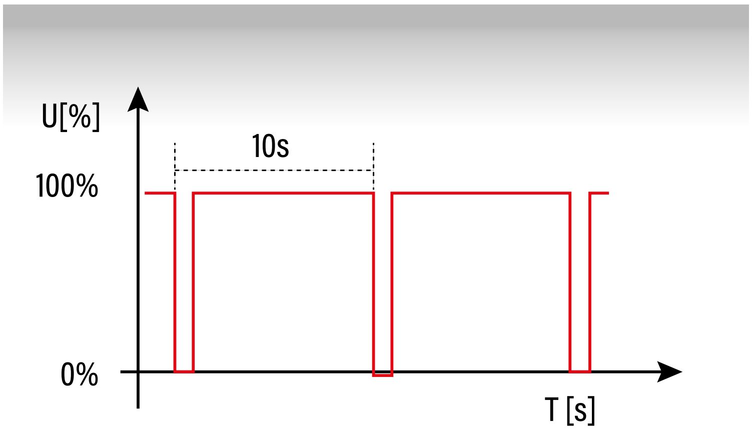
Visual representations of the testing requirements are shown in Figure 7.

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

[a] Classes as per IEC 61000-2-4; see Annex B
[b] To be defined by product committee. For connected directly or indirectly to the public network, the levels shall not be less severe than class 2
[c] “250/300 cycles” means “250 cycles for 50 Hz test” and “300 cycles for 60 Hz test”

Table 2

Preferred test levels and durations for short interruptions



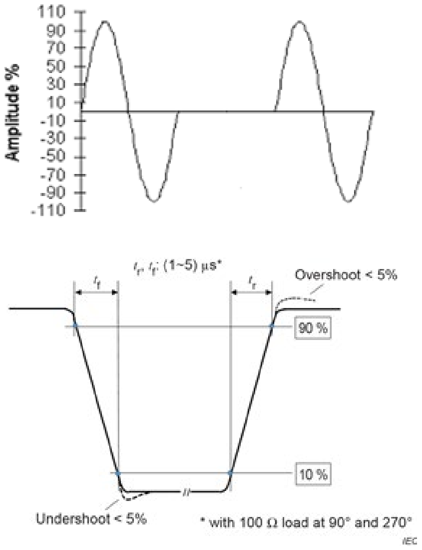


Figure 7

Diagrams for duty cycle, waveform, and fall/rise times of interruption testing

Voltage Interruption (Drop) Test Setup
For short interruptions, the angle must be defined by the product committee as the worst case. In the absence of definition, it is recommended to use 0°. For the short interruption test of three-phase systems, all the three phases must be simultaneously tested.
For the high impedance interruption test [Figure 8(a)] the EUT supply at PF1 is interrupted during the programmed time. The simulator interrupts the power supply line

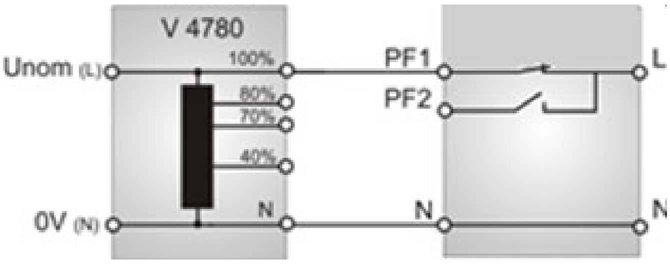


Figure 8a

Interruption high impedance

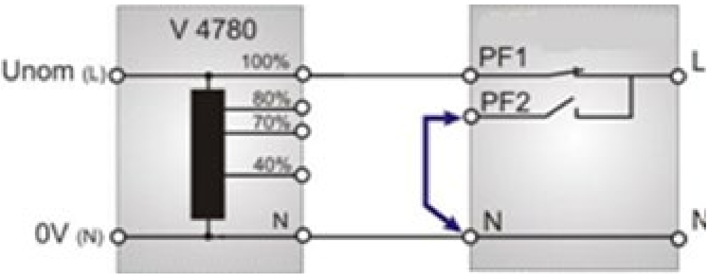


Figure 8b

Interruption low impedance

During low impedance interruption [Figure 8(b)], the EUT supply is interrupted by closing PF2 to 0V through a very low impedance path. The EUT is shorted and internal buffer capacitors are discharged. The simulator switches the supply to 0V and makes a short circuit at the EUT input

Voltage Variations

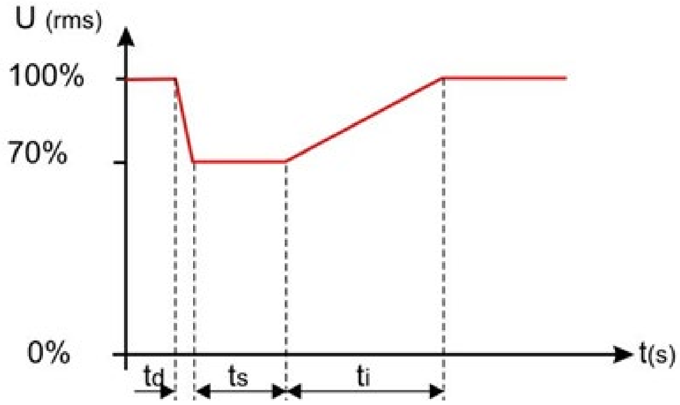


Figure 9 shows the RMS voltage as a function of time. As shown in Figure 9 the voltage change to the EUT will be abrupt (td) or between 1 – 5 µs, and then be at the reduced voltage (70%) for one cycle, and then gradually return to 100% over the course of 5000 ms using a motorized variac. Other values may be taken in justified cases and shall be specified by the product committee (Table 3).

Voltage test level	Time for decreasing voltage (t_d)	Time at reduced voltage (t_s)	Time for increasing voltage (t_i) (50/60 Hz)
70%	Abrupt	1 cycle	25/30[b] cycles
X[a]	X[a]	X[a]	X[a]

a To be defined by product committee
b “25/30 cycles” means “25 cycles for 50 Hz test” and “30 cycles for 60 Hz test”

Table 3
Timing of short-term supply voltage variations

Voltage Variation Test Setup

The voltage variation test will need a switch (Simulator below) in order to produce the abrupt decrease at the beginning of the disturbance and to control the variac produce a gradual return to mains voltage as shown in Figure 9 and Table 3.

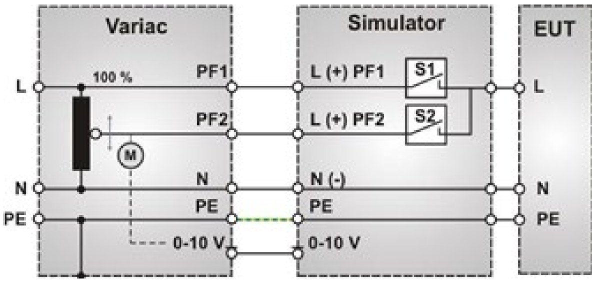
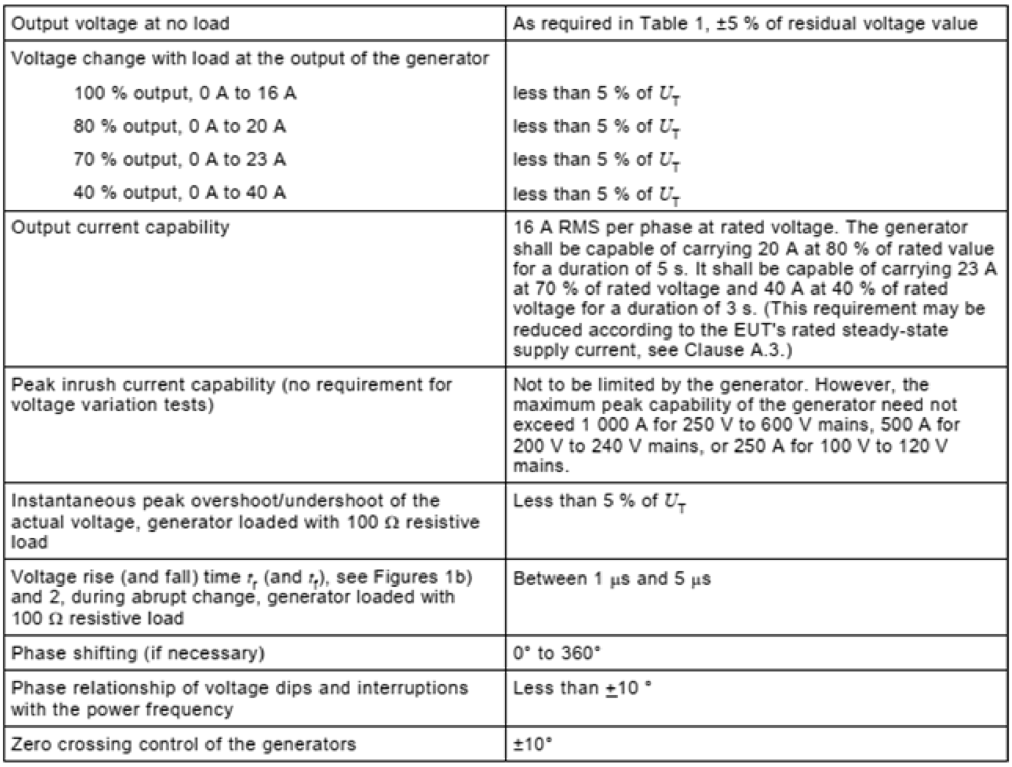


Figure 10
Test setup for voltage variation test

Generator specifications



Output voltage at no load	As required in Table 1, ±5 % of residual voltage value
Voltage change with load at the output of the generator	
100 % output, 0 A to 16 A	less than 5 % of U_T
80 % output, 0 A to 20 A	less than 5 % of U_T
70 % output, 0 A to 23 A	less than 5 % of U_T
40 % output, 0 A to 40 A	less than 5 % of U_T
Output current capability	16 A RMS per phase at rated voltage. The generator shall be capable of carrying 20 A at 80 % of rated value for a duration of 5 s. It shall be capable of carrying 23 A at 70 % of rated voltage and 40 A at 40 % of rated voltage for a duration of 3 s. (This requirement may be reduced according to the EUT's rated steady-state supply current, see Clause A.3.)
Peak inrush current capability (no requirement for voltage variation tests)	Not to be limited by the generator. However, the maximum peak capability of the generator need not exceed 1 000 A for 250 V to 600 V mains, 500 A for 200 V to 240 V mains, or 250 A for 100 V to 120 V mains.
Instantaneous peak overshoot/undershoot of the actual voltage, generator loaded with 100 Ω resistive load	Less than 5 % of U_T
Voltage rise (and fall) time t_r (and t_f), see Figures 1b) and 2, during abrupt change, generator loaded with 100 Ω resistive load	Between 1 µs and 5 µs
Phase shifting (if necessary)	0° to 360°
Phase relationship of voltage dips and interruptions with the power frequency	Less than ±10 °
Zero crossing control of the generators	±10°

Table 4

Generator specifications

Note that the 1 – 5 µs switching requirement only applies to the generator with a load of 100 Ω with minimal inductance.
During the connection of equipment to a power line, an inrush current flows into it. This inrush current could conceivably damage parts of the equipment, for example an input rectifier with capacitive smoothing. In order to prevent damage, measures for inrush current limitation are usually incorporated inside the equipment.

An inrush current will also occur when the line voltage recovers after a voltage dip or interruption. In this case, the inrush current limitation measures might not be activated in the equipment with disabled pre-charge circuit, so it is possible for the post-dip inrush current to damage the equipment.

For these reasons, it is necessary for the voltage dip generator to be capable of supplying sufficient current and that the post-dip inrush current is not limited by the dip generator. Without this inrush current requirement, it would be possible for the equipment to pass the immunity test performed with the dip generator, but to fail in the real world due to inrush current damage.

At the end of the day, while voltage dips and interruptions are inevitable; designing and testing devices to the concepts of IEC 61000-4-11 will go a long way to assure that these disturbances are unnoticeable as well.

About AMETEK CTS

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Aerospace and Defense
Consumer electronics
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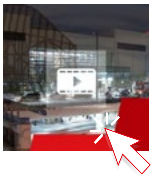

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