



# Unisin<sup>®</sup> 2100 Neutral Current Filter Harmonics in 3 Phase 4-Wire Systems

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## Harmonics in 3 Phase 4-Wire Systems

Computers, high frequency (energy saving) fluorescent lights, copiers and gaming machines, etc., generate harmonic currents throughout an electrical distribution system. The unbalanced portion of 60 Hz phase currents, plus third and other triplen (multiple of three) harmonic currents flow from each phase to the neutral conductor.

In 3 phase 4-wire systems the neutral conductor is subject to currents of all three phases, resulting in the possibility of up to 3 times the 60 Hz phase current flowing in the neutral conductor.

The flow of harmonics increases the root mean square of the current magnitude and so creates additional voltage drops across various circuit elements. The original sine wave of 60 Hz voltage is thus distorted. This distortion is called voltage distortion.

The most common adverse impacts of harmonics are listed as follows:

<i>CAUSE</i>	<i>EFFECTS</i>
Flow of Harmonics	<ol style="list-style-type: none"><li>1. Interference with telecommunications, telemetry, instrumentation and microprocessors</li><li>2. Poor voltage regulation</li><li>3. Transformer overheating</li><li>4. Capacitor failure</li></ol>
Increased RMS Current	<ol style="list-style-type: none"><li>1. High neutral-to-ground voltage (common mode noise)</li><li>2. Device malfunction</li><li>3. Poor power factor</li><li>4. Higher I<sup>2</sup>R losses</li><li>5. Malfunction of metering and protective devices such as circuit breakers and relays</li><li>6. Blown fuses due to excessive harmonic current</li></ol>
Voltage Distortion	<ol style="list-style-type: none"><li>1. Additional motor and generation loss leading to derating</li><li>2. Possibility of higher and flattened voltage peak</li><li>3. Device overheating</li><li>4. Device malfunction, particularly of electronic types, including computers, instrumentation and gaming machines</li></ol>

Risks due to harmonics can be categorized as obvious and hidden. Obvious risks require immediate action and include burnout of distribution transformers and overloading of the neutral conductor. Hidden risks may result in major problems that occur when other problems arise. For example a relay or circuit breaker may fail, resulting in a catastrophic failure. Prevention of catastrophic failure requires a full understanding of the behavior and effects of harmonics in an electrical system.

Creating the ideal electrical system that is free of harmonics is too costly to be practical and so the normal remedy for harmonics is based on engineering judgment that balances the system's ability to handle the load, including the harmonic load, against the cost of that remedy.

The optimum choice typically lies in eliminating certain specific harmonics so that the remaining harmonics in the system are low enough to not interfere with system operation.

Two major guidelines to consider when determining acceptable harmonic limits within a power distribution system, include:

1. Maintaining less than 5% total voltage distortion and 3% individual harmonic distortion at the point of utilization (IEEE Standard 519)
2. Limiting neutral-to-ground voltage (common mode noise) to the industry standard or manufacturer's criterion, which is normally less than 3.5 to 6.5 volts.

### **Voltage Distortion**

When electric power is supplied to nonlinear loads (such as computers, energy efficient fluorescent lights and gaming machines) harmonic currents are generated in the electrical system. In three phase 4-wire systems these harmonic currents circulate and thereby create harmonic voltages throughout the electrical system but mainly toward the source, which in a building is the main power transformer supplying loads in the building. Therefore at any point in the electrical system there is a combination of fundamental voltage (60 Hz) and harmonic voltages of frequencies that are integer multiples of the fundamental frequency. For example the 3<sup>rd</sup> harmonic voltage  $V_3$  is 180 Hz. Distortion of the 60 Hz system voltage is generally referred to as voltage distortion, and is expressed mathematically as:

$$\text{Voltage Distortion \%} = [(V_3^2 + V_5^2 + V_7^2 \dots)^{1/2}/V_1] \times 100$$

where  $V_1$  is the system 60 Hz voltage, and  $V_N$  are the harmonic voltages expressed in the same units as the system voltage (volts or per unit volts).

In three phase 4-wire systems there is a correlation between harmonic voltage distortion and neutral-to-ground voltage. If voltage distortion is reduced by reduction of 3rd harmonic currents, then the neutral-to-ground voltage will be reduced as well.

### **Determination of Maximum Allowable Harmonic Distortion**

Determination of the maximum allowable harmonic distortion and voltage distortion starts with the question: Above what level does harmonic distortion cause problems? The answer depends on the electrical equipment impacted. Some types of electrical equipment can tolerate high levels of distortion while other types such as certain electronic equipment, are very sensitive.

The IEEE Standard 519-1992, entitled "IEEE Recommended Practices and Requirements for Harmonics Control in Electrical Power Systems", Section 6.6 specifically addresses the issue of harmonics on electronic equipment:

*Power electronic equipment is susceptible to misoperation caused by harmonic distortion. This equipment is often dependent upon accurate determination of voltage zero crossings or other aspects of the voltage wave shape. Harmonic distortion can result in a shifting of the voltage zero crossing or the point at which one phase-to-phase voltage becomes greater than another phase-to-phase voltage. These are both critical points for many types of electronic circuit controls, and misoperation can result from these shifts.*

*Other types of electronic equipment can be affected by transmission of ac supply harmonics through the equipment power supply or by magnetic coupling of harmonics into equipment components. Computers and allied equipment such as programmable controllers frequently require ac sources that have no more than a 5% harmonic voltage distortion factor, with the largest single harmonic being no more than 3% of the fundamental voltage. Higher levels of harmonics result in erratic, sometimes subtle, malfunctions of the equipment that can, in some cases, have serious consequences.*

So according to IEEE, electronic equipment such as computers and allied equipment could have a problem if the Total Voltage Harmonic Distortion (THDV) exceeds 5% or if any single harmonic exceeds 3%. As a practical matter, the IEEE Standard 519 is a general guide for all users of electrical and electronic equipment. Optimum performance of some sensitive equipment, especially those controlled by microprocessors, may require even more stringent restrictions for voltage distortion and neutral-to-ground voltage.

***Power Quality Consultation***

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