

Keysight Technologies

Detecting Harmonics in an AC Signal

Application Note



Introduction

Harmonic distortion has become increasingly prevalent in today's world due to the expanded use of equipment and machinery. Because these devices can malfunction or fail in the presence of high harmonic voltage and/or current levels, harmonic distortion has become a growing concern for facility managers, users of automation equipment, and engineers. The presence of harmonics may not impede a factory's or office's ability to run properly, however, it depends on the withstand capability of the power distribution system and the susceptibility of the equipment. In this application note, you will learn some basics about harmonics and how to perform a quick check for harmonics in electrical power systems.

What are Harmonics?

Harmonics are electric voltages and currents that appear on the electric power system with frequencies that are integer multiples of the fundamental supply frequency, which is 50 Hz for European countries and 60 Hz for North America. For example, if the fundamental supply frequency is 60 Hz, then the second order harmonic is 120 Hz, the third order is 180 Hz, the fourth order is 240 Hz, and so on.

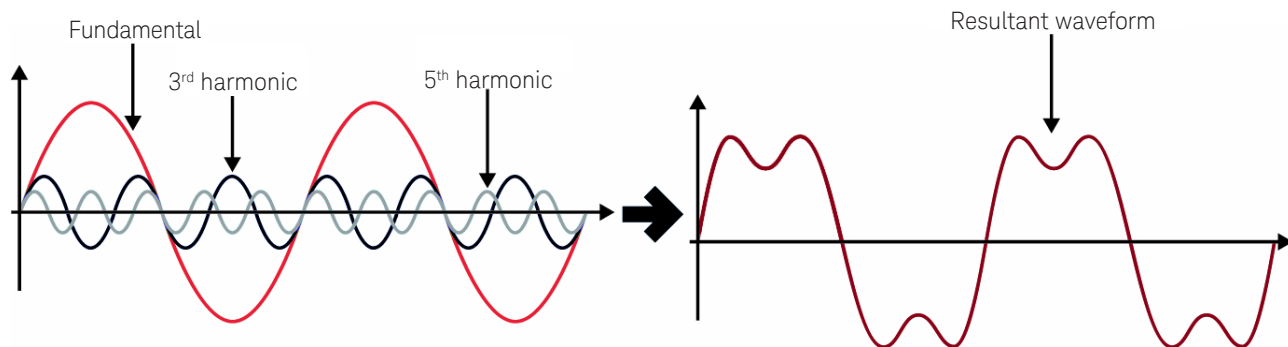


Figure 1. The resultant waveform of a sine wave with the presence of third and fifth order harmonics

What Causes Harmonics?

Harmonics are caused by modern electronic equipment having a non-linear load. These non-linear loads create harmonics by drawing current in abrupt short pulses. The short pulses cause distorted current waveforms which in turn causes harmonic currents to flow back into other parts of the power system. Harmonics are especially prevalent where there are a large number of personal computers, laser printers, fax machines, copiers, medical test equipment, fluorescent lighting, uninterruptable power supplies (UPSs), and variable speed drives.

Harmonics degrade the level of power quality and its efficiency, particularly in a commercial building or industrial facility. In general, most buildings can withstand non-linear loads of up to 15% of the total electrical system capacity without concern. If the non-linear loads exceed 15%, some non-apparent negative consequences can be expected.

Problems Caused by Harmonics

The following are some of the common problems caused by harmonics. The actual problems of any building will vary, depending on the types and number of installed harmonic-producing loads.

Overloading of neutral conductors

The three-phase system consists of three individual phase conductors and a neutral conductor. If all the phase conductors carry the same current, the phase currents tend to cancel out one another provided there is a balanced load. This balanced load makes it possible to reduce the size of the neutral conductor. Unfortunately, switched mode power supplies used in computers have very high third harmonic current. While harmonic currents cancel out on the neutral wire, the third harmonic current is additive in the neutral. In buildings with a large number of installed personal computers, the neutral wire can carry much higher currents than the wire was designed to accommodate, creating a potential fire hazard.

Overheating of transformers and increased associated losses

For transformers feeding harmonic-producing loads, the eddy current loss in the windings is the most dominant loss component in the transformer. This eddy current loss increases proportional to the square of the product's harmonic current and its corresponding frequency. The total transformer loss to a fully loaded transformer supplying to a non-linear load is twice as high as for an equivalent linear load. This causes excessive transformer heating and degrades the insulation materials in the transformer, which eventually leads to transformer failure.

Nuisance tripping of circuit breakers

All circuits containing capacitance and inductance have one or more resonant frequencies. When any of the resonant frequencies correspond to the harmonic frequency produced by non-linear loads, harmonic resonance can occur. Voltage and current during resonant frequency can be highly distorted. This distortion can cause nuisance tripping in an electrical power system, which can ultimately result in production losses.

Detecting Harmonics with the U1242 Series Handheld Multimeter



A harmonic analyzer is the most effective instrument for performing detailed analysis of power quality to determine the wave shapes of voltage and current on respective frequency spectrums. A harmonic analyzer is also useful in instances where the lack of obvious symptoms prevents you from determining if harmonics are a cause for concern.

To help technicians or electricians quickly identify if harmonics are present in the source, Keysight has introduced a new U1242 Series DMM feature called harmonic ratio. A harmonic analyzer is used to provide a detailed analysis of the suspect source. Using this data, the harmonic ratio function calculates a value from 0% to 100% to indicate the deviation of non-sinusoidal and sinusoidal waveform. This value indicates the presence of harmonics. A pure sinusoidal waveform without harmonics has a harmonic ratio of 0%. Measurements with a higher harmonic ratio show that more harmonics are present in the signal. Typically, a harmonic ratio of 5% is not much of a concern; anything above 10% will almost always cause you problems.

Figure 2 illustrates how the harmonic ratio is derived.

$$\text{Harmonic ratio (\%)} = \frac{V_{avg} - V_{rms}}{V_{rms}} \times 100\%$$

\downarrow
 \downarrow

V_{avg}
 V_{rms}

Figure 2. The harmonic ratio calculation

Table 1 shows the harmonic ratio derived based on an accuracy comparison of harmonic readings obtained using a true RMS DMM and an average responding-type DMM.

Table 1. Differential for true RMS, average responding, and the harmonic ratio

Waveform	True RMS	Average responding	Harmonic ratio
Pure sine wave	Accurate	Accurate	0%
Square wave	Accurate	10% higher	-10%
1-phase diode rectifier	Accurate	40% lower	40%
3-phase diode rectifier	Accurate	5 to 30% lower	5 to 30%
Sawtooth	Accurate	13.3% higher	-13.3%

Conclusion

With the built-in harmonic ratio function, the Keysight U1242 Series handheld DMM helps technicians and engineers quickly verify the presence of harmonics in AC signals. This information can be used to prevent or reduce equipment downtime and repair costs.

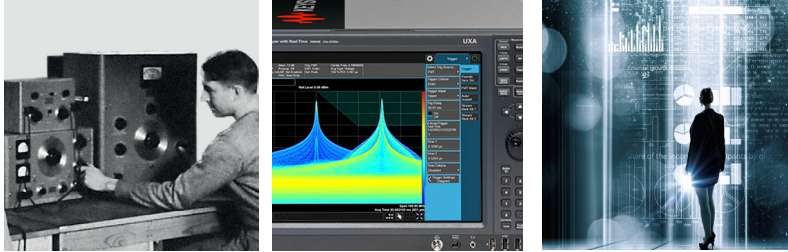
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