HARMONICS - Understanding the Facts - Part 3

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Abstract

Understanding what is important to know about harmonics can be challenging for those without extensive electrical engineering backgrounds. This is third and final part of a three part series. This part will provide details on what causes harmonic problems and suggested solutions.

What they look like

One recent survey showed the percentage the total electrical consumption by non-linear loads will double from the year 1985 to 2000. The AC-DC converter used in the switching-type power supplies found in most personal computers and peripheral equipment, such as printers, is an example of a non-linear load. While they offer many benefits in size, weight and cost, the large increase of equipment using this type of power supply over the past fifteen years is largely responsible for the increased attention to harmonics.

Figure 1 shows how the first stage of a switching-type power supply works. The AC voltage is converted into a DC voltage, which is further converted into other voltages that the equipment needs to run. The rectifier consists of semi-conductor devices (such as diodes) that only conduct current in one direction. In order to do so, the voltage on the one end must be greater than the other end. These devices feed current into a capacitor, where the voltage value on the capacitor at any time depends on how much energy is being taken out by the rest of the power supply.

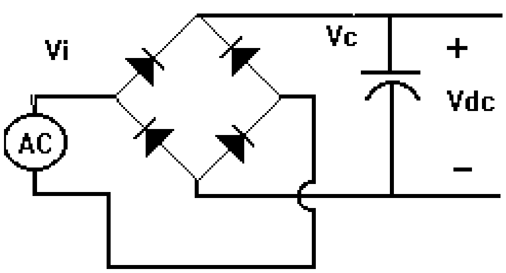


Figure 1. Typical AC-DC Converter

When the input voltage (Vi) is higher than voltage on the capacitor (Vc), the diode will conduct current through it. This results in a current waveform as shown in Figure 2, and harmonic spectrum in Figure 3.   Obviously, this is not a pure sinusoidal waveform with only a 60 Hz frequency component.

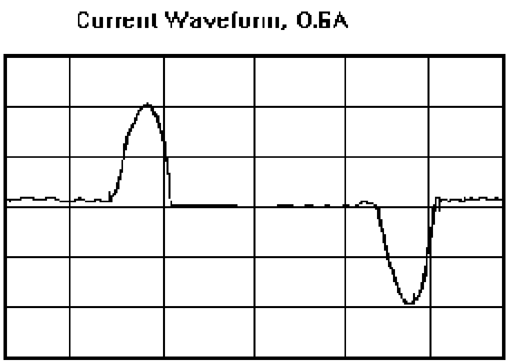
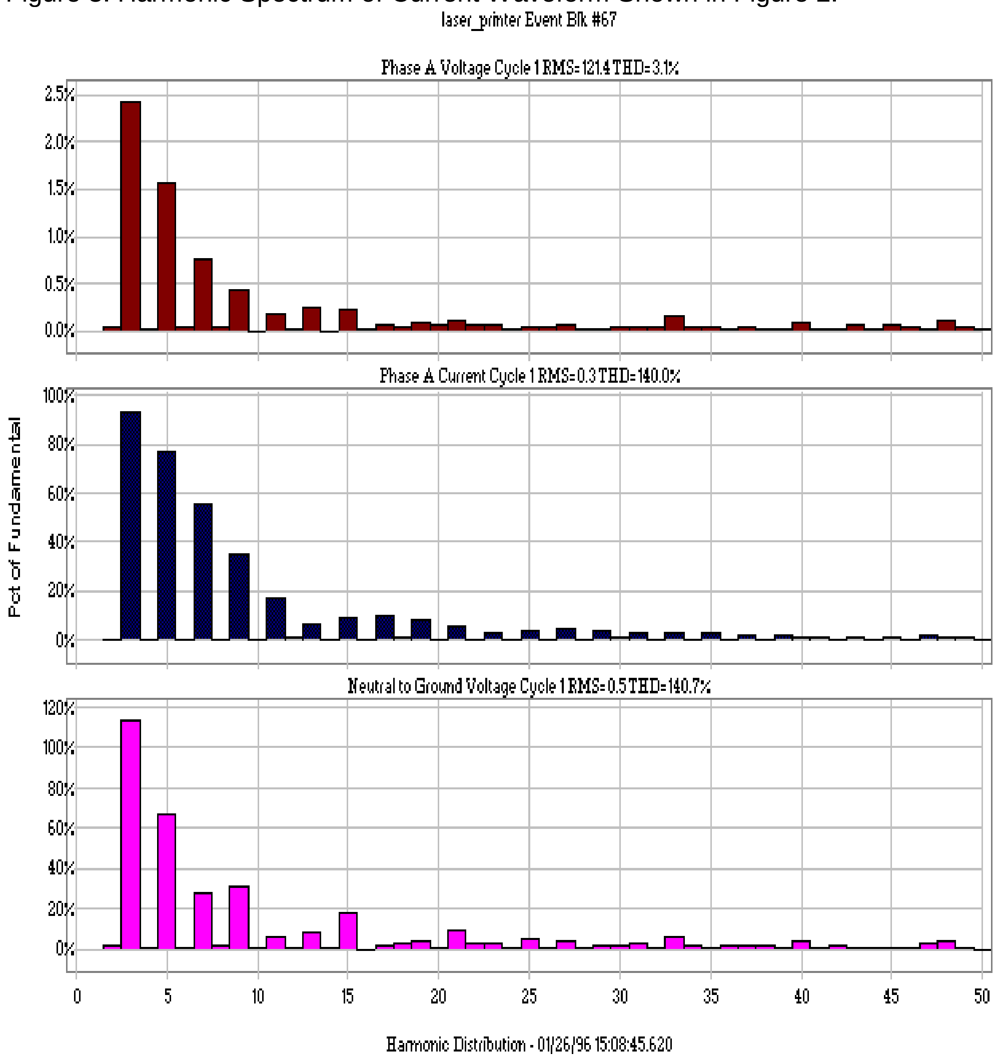


Figure 2. Current Waveform

Figure 3. Harmonic Spectrum of Current Waveform Shown in Figure 2.



If the rectifier had only been a half-wave rectifier, the waveform would only have every other current pulse, and the harmonic spectrum would be different. Whereas the above harmonic spectrum contains only odd harmonics for current, the spectrum for the current of a half wave rectified circuit would only have even harmonics.

Certain types of loads also generate typical harmonic spectrum signatures, that can point the investigator towards the source. This is related to the number of pulses, or paths of conduction. The general equation is h = (n * p) +/- 1, where h is the harmonic number, n is any integer (1,2,3,..) and p is the number of pulses in the circuit. Table 4 shows examples of such. The magnitude decreases as the ratio of 1/h (1/3, 1/5, 1/7, 1/9,...).

Type of device	Number of pulses	Harmonics present
half wave rectifier	1	2,3,4,5,6,7....
full wave rectifier	2	3,5,7,9,...
three phase, full wave	6	5,7, 11,13, 17,19,...
(2) three phase, full wave	12	11,13, 23,25, 35,37,...

Table 4. Typical Harmonics Found for Different Converters.

When transformers are first energized, the current drawn is different from the steady state condition. This is caused by the inrush of the magnetizing current. The harmonics during this period varies over time. Some harmonics have a negligible value for part of the time, and then increase for a while before returning to basically zero. An unbalanced transformer (where either the output current, winding impedance, or input voltage on each leg are not equal) will cause harmonics, as will overvoltage saturation of a transformer.

Fluorescent lights can be the source of harmonics, as the ballasts are non-linear inductors. The third harmonic is the predominate harmonic in this case. (See Table 3) As previously mentioned, the third harmonic current from each phase in a four-wire wye or star system will be additive in the neutral, instead of canceling out Some of the newer electronic ballasts have very significant harmonic problems, as they operate somewhat like a switching power supply, but can result in current harmonic distortion levels over 30%.

Harmonic # (Current)	Percent of Fundamental
2	4%
3	20%
4	1%
5	10%
6	1%
7	5%
9	6%

Table 3. Sample of Harmonic Values for Fluorescent lighting [4].

The process of melting metal in an electric arc furnace can result in large currents that are comprised of the fundamental, interharmonic, and subharmonic frequencies being drawn from the electric power grid. These levels can be quite high during the melt-down phase, and usually effect the voltage waveform.

How do you get rid of them

Care should be undertaken to make sure that the corrective action taken to minimize the harmonic problems don't actually make the system worse. This can happen as the result of resonance between harmonic filters, PF correcting capacitors and the system impedance. Examples of ways to minimize the harmonic problems include:

- Isolating harmonic pollution devices on separate circuits with or without the use of harmonic filters.

- Loads can be relocated to try to balance the system better.

- Phase shifted transformers, such as "zig-zag transformers", can be used to cancel out specific harmonics by making one voltage circuit 180 degrees out-of-phase from another.

- Neutral conductors should be properly sized according to the latest NEC-1996 requirements covering such. Where as the neutral may have been undersized in the past, it may now be necessary to run a second neutral wire that is the same size as the phase conductors. This is particularly important with some modular office partition-type walls, which can exhibit high impedance values.

- The operating limits of transformers and motors should be derated, in accordance with industry standards from IEEE, ANSI and NEMA on such.

- Use of higher pulse converters, such as 24-pulse rectifiers, can eliminate lower harmonic values, but at the expense of creating higher harmonic values.

Summary

Harmonics are here to stay. But the amount of harmonic voltage and current levels that a system can tolerate is dependent on the equipment and the source. Ongoing preventive maintenance programs that include harmonic monitoring can detect problems in the making, eliminating costly failures. Knowing what your system harmonic levels presently are, what the effect of new equipment being added will due to these levels, and how much of an increase in harmonic levels that your system can tolerate are valuable pieces of information that are readily attainable from modern power quality/harmonic analyzer monitoring equipment.

References

National Electrical Code - NEC-1996, National Fire Protection Association