Harmonics

What are Harmonics? Can they impact AC Drive Sales

The greatest problem with Harmonics is the lack of information about harmonics. Our customers and the electric utilities that service our customers are asking questions about harmonics from our drives using the IEEE 519 guide as the basis for drive selection. There is a lot of confusion about what the IEEE guide means, so the tendency by our customers to fix their requirements on the exact value for percent harmonic distortion defined in the IEEE guide. The intent of this harmonic session is to show you how to use the harmonic analysis program contained on the energy saving diskette and to prepare you to better assist your customers in dealing with their concerns, specifications requirements for the equipment and utility rebate programs.

Let's start with the basics.

When we talk about ac we are talking about alternating current. The voltage pushing that current through the load circuit is described in terms of frequency and amplitude. The frequency of the current will be identical to the frequency of the voltage as long as the load resistance/impedance does not change. In a linear load, like a resistor, capacitor or inductor, current and voltage will have the same frequency. As long as the characteristics of the load components do not change, the frequency component of the current will not change. When we deal with non-linear loads such as switching power supplies, transformers which saturate, capacitors which charge to the peak of the supply voltage, and converters used in drives, the characteristics of the load are dynamic. As the amplitude of the voltage changes and the load impedance changes, the frequency of the current will change. That changing current and resulting complex waveform is a result of: these load changes. The complex current waveform can be described by defining each component of the waveform. The component of any waveform can be defined in terms of dc, and all frequencies from 0 to infinity. The frequencies that are normally dealt with using drives are 50 and 60 Hertz. By definition, these frequencies are termed fundamental in their respective distribution systems.

Let's get into harmonics basics level II .

With three phase conversion equipment, such as drives, the current demand on the distribution system will depend on three things. They are the characteristics of the input three phase voltage, the operating speed of the drive, and the drive output load demand. Evaluating a single operating point of a drive will permit determining the input current demand and the cause of the harmonic content of that input current.

Let's define the operating point for the evaluation.

Input voltage-line = 480 VAC, Full load amps = 100, Output Frequency 60 Hz These value will be used in the following text as the example system.

The drawing shown indicates how current follows the frequency when the load is linear Only a phase angle change is shown.

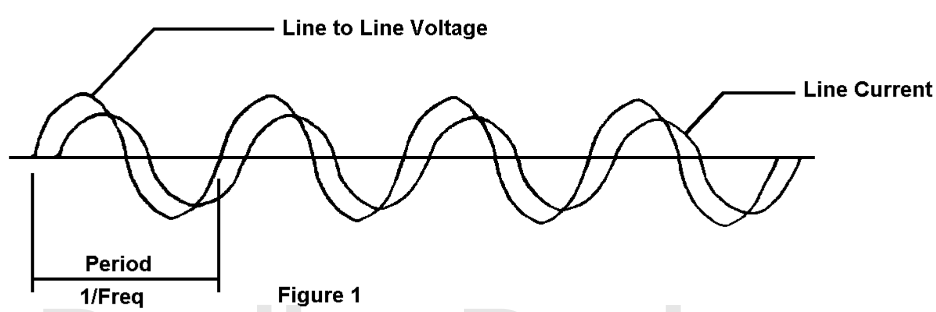

Figure 1

When the load become non-linear, the current is not continuous and will contain many Frequencies. Figure 2 shows what the current might look like in a non-linear circuit.

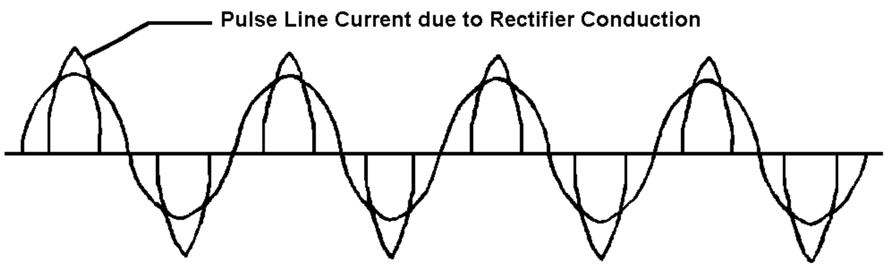

Figure 2

Each current pulse will contain many frequencies. The frequencies will be made up of the fundamental, 60 Hz, and frequencies which are a multiple or sub-multiple of the fundamental. The description can be mathematically defined by a Fourier series. Since the pulses are of both polarities, the even order harmonics will be canceled. In a three phase circuit, any harmonic divisible by 3 will be canceled in each phase. However, the sum of those harmonics divisible by 3 will be found in the neutral of the distribution system. It is for that reason the neutral wire in a distribution system is often sized to carry up to three times the value of the phase currents.

For distribution systems which must handle a large percentage of non-linear loads, the percentage of harmonic currents can be very high. It is important to remember that the greatest contributor to harmonic currents is single phase lighting circuits which used magnetic or electronic lighting controls. The next largest contributor is computers. In fact, any single phase device which contains a switching mode power supply, a SMPS, will cause high percentages of the third harmonic. The third harmonic causes the greatest amount of current distortion on the ac line. In factories and office buildings where the load type is lighting and computers, that type of load is often as much as 50% of the total power used. The addition Of non-linear, 3 phase drive products, whether ac or dc, is usually less than 20% of the total load. Since the most significant harmonic in a three phase load is the fifth harmonic, the current distortion caused by drives is much less than caused by lighting and computer loads.

So why all the fuss about harmonic currents caused by drives?

The main reason for the concern is that drives must be considered since they can add to the harmonic currents already present. It the harmonic currents are not considered, it would be like ignoring some of the loading when picking a transformer or the wire size in a distribution system. If the transformer is sized too small, it could cause a fire. Using a standard transformer, with exactly the listed KVA load for each drive or non-linear load is like using too small a transformer. A 50 KVA SMPS lighting load would require 65 KVA due to the 33% additional 3rd harmonic current load. The higher frequency harmonic current will cause more transformer heating because of eddy current losses in the core and higher wire resistance caused by skin effect.

There are two main affects of harmonic currents on a distribution system. The first is that harmonic currents add to the RMS value of the fundamental. This additional current will increase losses in wire, bus bars, transformers and power factor correction capacitors used in the distribution system. A typical value for the additional RMS loss would be 3% if skin effect and core losses could be ignored. Unfortunately, they can not be ignored. The second affect is the additional heating caused by each of the harmonic currents. Transformers, capacitors, circuit breakers, wires and bus bars must be designed to handle the higher frequency currents. If these components are not correctly sized for the harmonic currents, the harmonic currents can cause additional heating in those components. This heating can result in premature component failure and the possibility of fire. New transformer ratings will soon be on the market. These ratings will cover transformers for non-linear loads. Underwriters Laboratory, UL will begin to rate transformer based on the percentage of non-linear loads, whether single phase or three phase.

In a six pulse converter or 3 phase full-wave bridge, the most significant harmonics are the number of pulses ±1. That means a six pulse converter will create harmonic currents with a frequency 5 times 60 Hz and 7 times 60 Hz. The amplitude of those harmonics will be approximately 1/5 and 1/7 of the amplitude of the fundamental current. In the example, a fundamental or 60 Hz current of 100 amps would contain a 300 Hz current with an amplitude of 1/5 times 100 or 20 amps and a 420 Hz current with an amplitude of If 7 times 100 or 14.3 amps. In RMS terms, the harmonic current distortion value will only amount to approximately:

$$\sqrt{100^2+20^2+14.3^2} = 102.98$$

This additional 3% RMS current would not significantly overheat the components in a distribution system that is not overloaded and used components rated for non-linear loads. 1t linear load rated transformers and capacitors are used, the heating caused by 20% of the 5th harmonic and 14.3% of the 7th harmonic could cause destructive heating if the components are not derated. The chief concern with harmonic currents is that their characteristic are known so that correct sizing can take place.

How can harmonic currents affect AC drive sales?

Our principle concern should be how to deal with the concern or “fear” that our customers are likely to have regarding harmonic currents. We need to provide as much "good" information as possible without confusing the customer. These basic facts can be given to the customer concerned with harmonic currents and IEEE 519 guideline for harmonic currents.

1. Harmonic currents can cause overheating of distribution system equipment.

2. Harmonic currents are caused by any electrical equipment that used SMPS.

3. Distribution system loading by non-linear equipment can cause older dry type transformers to overheat if not derated.

4. Lighting accounts for 55% of all electrical power used. An estimated 90% of that power is controlled by some type of switching mode power supply (SMPS). That means that 50% of all power used can have harmonic currents overloading transformers, capacitors and other components on the distribution system.

5. Motors account for 40% of all electrical power used. An estimated 20~ Of that power is controlled by some type of 3 phase SMPS. That means that 8% of all power used for controlling motors can have harmonic currents overloading transformers, capacitors and other components on the distribution system.

6: Harmonic current will cause .voltage distortion The amount of distortion is much less than the distortion caused by the normal line current. Voltage distortion by high frequencies will be a percentage of the voltage drop caused by the fundamental current. A 5% drop in line voltage due to the fundamental load current will be increased by the 5th harmonics by 20% of 5% or an additional 1%.

7. Transformers, circuit breakers, and other distribution system components ratings within any facility Should be reviewed based on the original selection and any changes or additions in non-linear loads.

8. Single phase loads, such as lighting loads should be reviewed to determine what level of harmonic current distortion already exists in a system before adding additional non-linear loads to that system.

9. 0f the different types of AC drives on the market, the AC drive which causes the lest amount of harmonic current and voltage distortion over the operating speed range is a PWM AC drive which contains an internal dc bus reactor. The second best is a PWM AC drive with an AC line reactor before the drive.

10. The use of line filters before a drive will add more losses to the electrical system and could create line ringing and large voltage transients. These conditions could results in greater damage to other components on the distribution system. Even if correctly designed for an installation, the filter may have to be modified every time an additional piece of equipment is added to that distribution system.