AN INTRODUCTION TO POWER SYSTEM HARMONICS

Introduction

The objective of the electric utility is to deliver sinusoidal voltage at fairly constant magnitude throughout their system. This objective is complicated by the fact that there are loads on the system that produce harmonic currents. These currents result in distorted voltages and currents that can adversely impact the system performance in different ways.

As the number of harmonic producing loads has increased over the years, it has become increasingly necessary to address their influence when making any additions or changes to an Installation.

To fully appreciate the impact of this phenomena, there are two important concepts to bear in mind with regard to power system harmonics. The first is the nature of harmonic-current producing loads (non-linear loads) and the second is the way in which harmonic currents flow and how the resulting harmonic voltages develop.

Linear and non-linear loads

A linear element in a power system is a component in which the current is proportional to the voltage. In general, this means that the current wave shape will be the same as the voltage (See Figure 1). Typical examples of linear loads include motors, heaters and incandescent lamps.

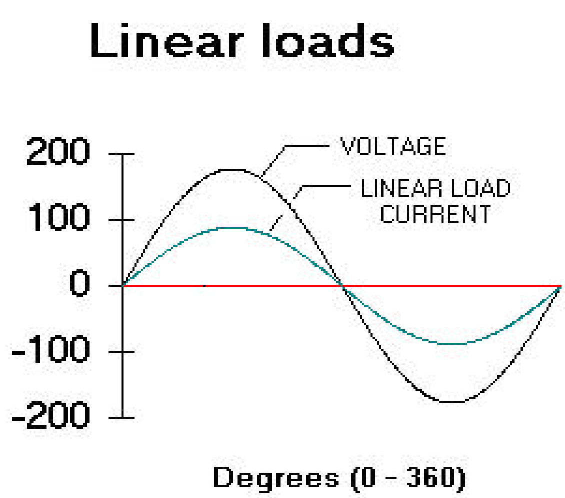

Figure 1 – Voltage and current waveforms for linear

On the other hand, the current wave shape on a non-linear load is not the same as the voltage (See Figure 2). Typical examples of non-linear loads include rectifiers (power supplies, UPS units, discharge lighting), adjustable speed motor drives, ferromagnetic devices, DC motor drives and arcing equipment.

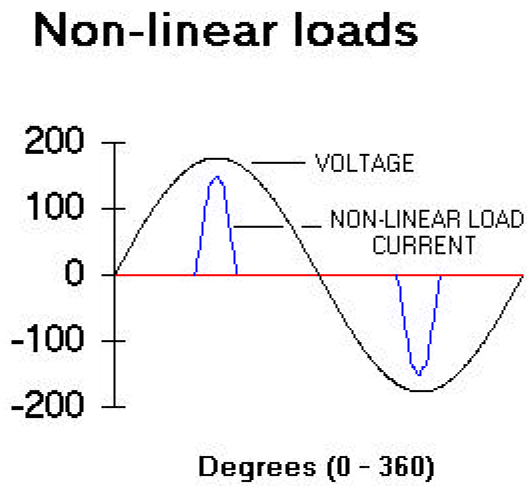

Figure 2 – Voltage and current waveforms for non-linear loads

The current drawn by non-linear loads is not sinusoidal but it is periodic, meaning that the current wave looks the same from cycle to cycle. Periodic waveforms can be described mathematically as a series of sinusoidal waveforms that have been summed together (See Figure 3).

The sinusoidal components are integer multiples of the fundamental where the fundamental, in the United States, is 60 Hz. The only way to measure a voltage or current that contains harmonics is to use a true-RMS reading meter. If an averaging meter is used, which is the most common type, the error can be Significant.

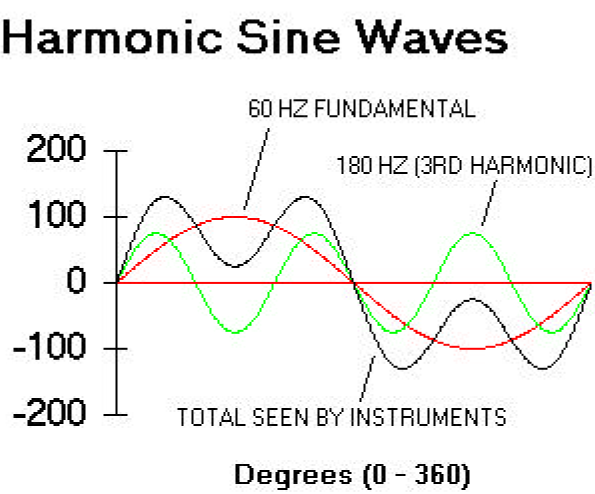

Figure 3. Waveform with symmetrical harmonic components

Each term in the series is referred to as a harmonic of the fundamental. The third harmonic would have a frequency of three times 60 Hz or 180 Hz. Symmetrical waves contain only odd harmonics and un-symmetrical waves contain even and odd harmonics.

A symmetrical wave is one in which the positive portion of the wave is identical to the negative portion of the wave. An un-symmetrical wave contains a DC component (or offset) or the load is such that the positive portion of the wave is different than the negative portion. An example of un-symmetrical wave would be a half wave rectifier.

Most power system elements are symmetrical. They produce only odd harmonics and have no DC offset. There are exceptions, of course, and normally-symmetrical devices may produce even harmonics due to component mismatches or failures. Arc furnaces are another common source of even harmonics but they are notorious for producing both even and odd harmonics at different stages of the process.

Harmonic current flow

When a non-linear load draws current, that current passes through all of the impedance that is between the load and the system source (See Figure 4). As a result of the current flow, harmonic voltages are produced by impedance in the system for each harmonic.

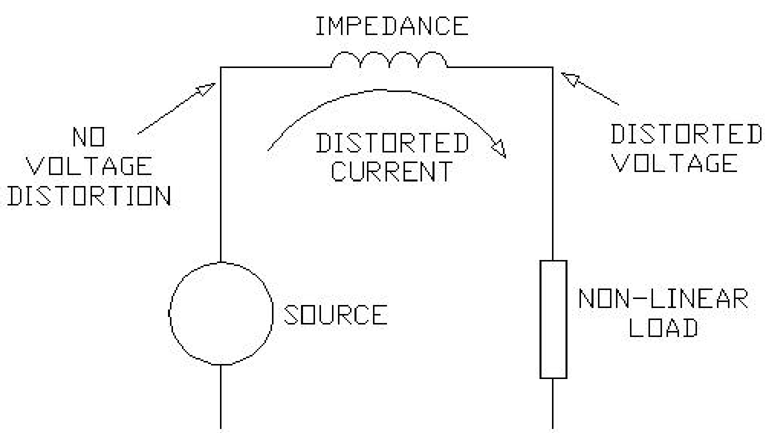

Figure 4 – Distorted-current induced voltage distortion

These voltages sum and when added to the nominal voltage produce voltage distortion. The magnitude of the voltage distortion depends on the source impedance and the harmonic voltages produced.

If the source impedance is low then the voltage distortion will be low. If a significant portion of the load becomes non-linear (harmonic currents increase) and/or when a resonant condition prevails (system impedance increases), the voltage can increase dramatically.

Power systems are able to absorb a considerable amount of current distortion without problems and the distortion produced by a facility may be below levels recommended in IEEE 519. However, the collective effect of many industrial customers, taken together, may impact a distribution system. When problems arise, they are usually associated with resonant conditions.

Harmonic currents can produce a number of problems, namely:

Equipment heating
Equipment malfunction
Equipment failure
Communications interference
Fuse and breaker mis-operation
Process problems
Conductor heating

Conclusion

Harmonic currents can have a significant impact on electrical distribution systems and the facilities that they feed. It is important to consider their impact when contemplating additions or changes to a system. In addition, identifying the size and location of non-linear loads should be an important part of any maintenance, troubleshooting and repair program.

This article was intended to provide an introduction to the basic principles of power system harmonics. Additional information can be obtained by calling Power Systems Engineering at 253-639-8535 or referring to the resources outlined below.

Additional resources:

1. R.C. Dugan, D.T. Rizy, “Harmonic Considerations for Electrical Distribution Feeders”, National Technical Information Service, Report No. ORNL/Sub/81-95011/4 (Cooper Power Systems as Bulletin 87011, “Electrical Power System Harmonics, Design Guide”)

2. J. Arillaga, et al, “Power System Harmonics” ISBN 0-471-90640-9

3. 4. P519A Task Force, Harmonics Working Group (IEEE PES T&D Committee) and SCC22 – Power Quality, “Guide for Applying Harmonic Limits on Power Systems” (Un-approved draft)

4. IEEE Standard 519-1992, IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems.