

# Causes of Harmonics on your power system



Electric Trains are a non-linear load that can introduce harmonics to a power system

Harmonics are voltages or currents in the electrical system that are at some frequency that is a multiple of the fundamental frequency. The fundamental frequency varies by region: for example, in North America the fundamental frequency is 60hz, but in Europe and South Africa it is 50hz. Harmonics cause unwanted heat on your system, which leads to both power losses and excessive wear and tear of electrical equipment. Harmonics also distort system voltages, and interfere with system control and telecommunications. It is important to reduce the impact of harmonics, but before you can do that, you need to know what causes them.

## But what causes harmonics?

Harmonics are caused by non-linear loads on a power system. Typically, electric current is produced as a sine wave: these loads draw power that is not a sine wave, and as a result, produce harmonics. IEEE Std 141-1993 (page 446-447) gives an excellent list of devices that might cause harmonics on your system:

- Arc furnaces and other arc-discharge devices, such as fluorescent lamps
- Resistance welders (impedance of the join between dissimilar metals is different for the flow of positive vs negative current)
- Magnetic cores, such as transformer and rotating machines that require third harmonic current to excite the iron
- Synchronous machines (winding pitch produces fifth and seventh harmonics)
- Variable speed drives used in fans, blowers, pumps, and process drives
- Solid-state switches that modulate the current-to-control heating, light intensity, etc.
- Switched-mode power supplies, used in instrumentation, PCs, televisions, etc.
- High-voltage dc transmission stations (rectification of ac to dc, and dc to ac invertors)
- Photovoltaic invertors converting dc to ac.

A lot of these devices generate very small harmonics, so if you recently installed a large amount of them you should check to make sure that their harmonics aren't having a cumulative effect on your system. A few of the more important things to watch out for are the switched-mode power converters and resonance. The majority of this information comes from IEEE Std 141, which I cannot recommend enough to anyone who deals with power systems.

## Switched-Mode Power Converters

Switched mode power converters come in two main types: single-phase converters, and three-phase, six-pulse converters.

### Single-Phase Converters

Single phase converters use capacitive elements instead of resistive elements. This means that output voltages can remain stable for a large variety of input voltages and currents. This makes them ideal for silicon chip devices like computers. As long as the capacitor is at full charge, the device won't draw current, meaning that there are periods of time where no current is flowing to your computer. This gives it a very high third-harmonic component, which essentially acts as a very high neutral current. So if you've recently added a lot of computers to your power system, and are experiencing high neutral currents, this may be the cause. The third-harmonic can be as high as 81% of the value of the main current!

### Three-Phase, Six-Pulse Converters

Three-phase converters are used extensively in variable speed drives and constant-voltage rectifiers. Similar to the single-phase converters, these have high sixth, ninth,

etc. harmonic currents. In addition, they also have smaller harmonic currents for 5th, 7th, 11th, 13th, etc. harmonics. If not properly grounded, the 6th harmonic can produce a current through the bearings of a dc or ac machine.

## Resonance

Resonance happens when the inductive reactance and capacitive reactance of your system are equal at a certain frequency. This becomes a problem if the reactance of your system is

resonant at the same frequency as a harmonic (in North America that means multiples of 60, or 120/180/240/300/360/etc.). There are two types of resonance: parallel and series.

### Parallel Resonance

Parallel Resonance occurs when the inductive and capacitive elements are in parallel, and are equal at some frequency. If a harmonic shares this frequency, then the resonant circuit will be excited and cause a large amount of current to oscillate between the inductive element and the capacitive element. This can cause excessive voltage distortion.

### Series Resonance

Series Resonance occurs when the inductive and capacitive elements are in series, and are equal at some frequency. If a harmonic shares this frequency, the series resonant circuit will draw all of the harmonic current, resulting in elevated current magnitudes across the circuit, as well as high voltage distortion between the inductive and capacitive elements of the circuit.

Hopefully now you have a better understanding of what can cause harmonics, and will be able to identify if any devices in your system are causing harmonics that need to be dealt with.