

POWER QUALITY AND HARMONIC DISTORTION

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Abstract - The harmonics generated by nonlinear loads in residential, commercial and office loads in distribution feeders and estimates the energy losses due to these harmonics. Incidence of harmonic related problems is low, but awareness of harmonic issues can help to increase plant power system reliability. On the rare occasions that harmonics are a problem, it is either due to the magnitude of the harmonics produced or a power system resonance. Harmonics are often accompanied by a temperature rise; thermography can be used to detect evidence of their presence. This paper will discuss the causes, effects, and symptoms of harmonics as well as techniques for dealing with harmonics.

Key Words: Basic concept of harmonics¹, Causes of harmonics, Effect of harmonics².

1. INTRODUCTION

Harmonics are caused by non-linear loads that is loads that draw a non sinusoidal current from a sinusoidal voltage source. It presents an overview of the various problems harmonic currents can create. Most of them are either related to different kinds of overloading – leading to problems of efficiency loss and overheating – or to disturbances of control and safety devices. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors.

2. BASIC CONCEPT OF HARMONIC

A pure sinusoidal voltage is a conceptual quantity produced by an ideal AC generator built with finely distributed stator and field windings that operate in a uniform magnetic field. Since neither the winding distribution nor the magnetic field are uniform in a working AC machine, voltage waveform distortions are created, and the voltage-time relationship deviates from the pure sine function. The distortion at the point of generation is very small (about 1% to 2%), but nonetheless it exists. Because this is a deviation from a pure sine wave, the deviation is in the form of a periodic function, and by definition, the voltage distortion contains harmonics.

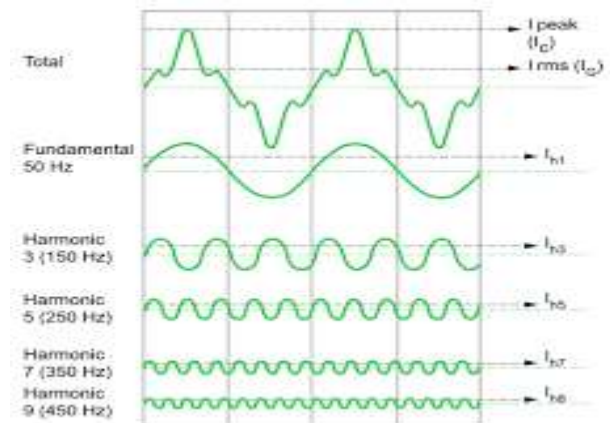
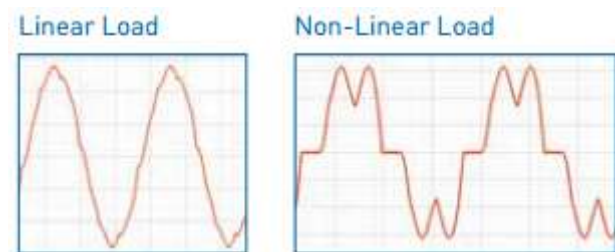


Fig. Basic dia of harmonic distortion

2.1 The Two Types of Loads

A power system can contain one or two different kinds of loads, a non-linear load or a linear load.



2.2 Linear Loads

Linear Loads have a current waveform that is proportional to the amount of voltage applied. If the voltage doubles the current doubles as well, maintaining a near perfect sine wave, reading no harmonics. Examples of the types of linear loads are: incandescent lamps, heaters, and resistors.

2.3 Non-linear Loads

When current is not proportional to the voltage, the load is classified as non-linear. Non-linear loads are most associated with modern electronic equipment that often relies on line-operated

3. CAUSES OF HARMONICS

Harmonics are caused by non-linear loads, that is loads that draw a non sinusoidal current from a sinusoidal voltage source. Some examples of harmonic producing loads are electric arc furnaces, static VAR compensators, inverters, DC

converters, switch-mode power supplies, and AC or DC motor drives. In the case of a motor drive, the AC current at the input to the rectifier looks more like a square wave than a sine wave

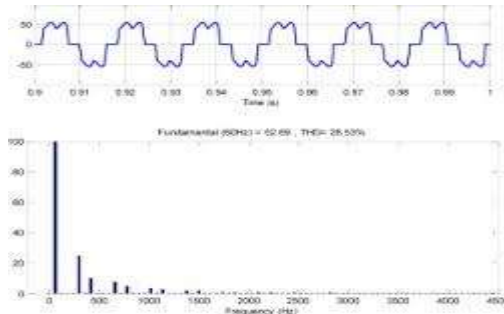


Fig. six-Pulse Rectifier Input Current Waveform

The rectifier can be thought of as a harmonic current source and produces roughly the same amount of harmonic current over a wide range of power system impedances. The characteristic current harmonics that are produced by a rectifier are determined by the pulse number. The following equation allows determination of the characteristic harmonics for a given pulse number:

$$h = k \cdot q \pm 1 \text{ where}$$

h is the harmonic number

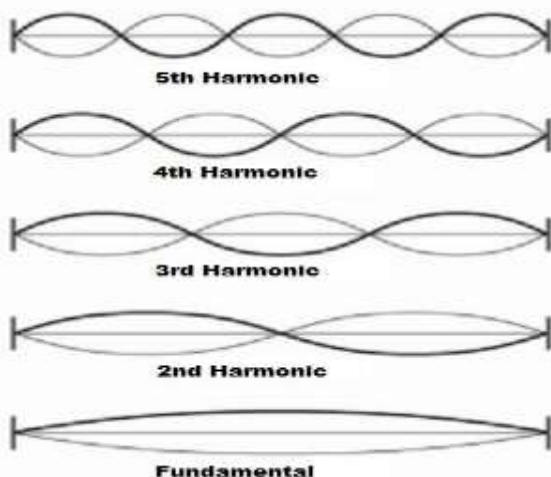
(integer multiple of the fundamental)

k is any positive integer

q is the pulse number of the converter.

4. EFFECTS OF HARMONIC DISTORTION

Harmonics are defined as waveforms at multiples of frequency of the fundamental input signal. For the 50Hz AC waveform (the fundamental or the 1st harmonic frequency) above, the harmonics will look like:

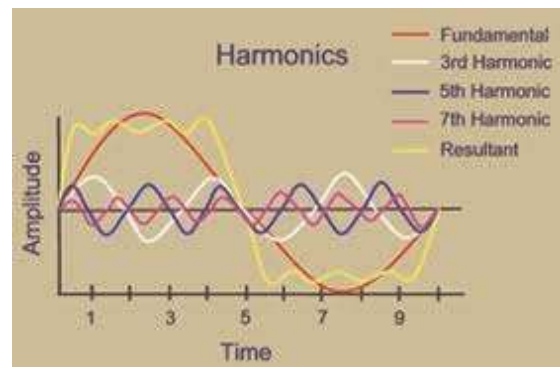


The 2nd, 5th, 8th etc Harmonics create a negative torque on motors running from the 3-phase supply. The motor will consume electrical energy to overcome the counter-torque created by the Negative Sequence Harmonics.

The 4th, 7th, 10th etc Harmonics create a positive torque on motors running of the 3-phase supply. These are called Positive Sequence Harmonics.

The interaction between the positive and negative sequence harmonics in an electrical system produces torsional oscillations in the motor shaft. These oscillations can be potentially catastrophic if the frequency resonates with the natural mechanical frequency of the motor shaft itself. It is important that for large VFD motor installations, harmonic analyses be performed to determine the levels of harmonic distortions and assess their impact on the motor. The presence of harmonics also raises the operating temperature of the motor. In a paper published[1] in the Industrial and Commercial Power Systems Technical Conference (1998 IEEE), the presence of the 3rd harmonic in a VFD installation operating at 10% efficiency can cause the temperature of the motor to rise by 6°C.

4.1 Effect of Harmonic Distortion in Power System



Power systems designed to function at the fundamental frequency, which is 60-Hz in the United States, are prone to unsatisfactory operation and, at times, failure when subjected to voltages and currents that contain substantial harmonic frequency elements. Very often, the operation of electrical equipment may seem normal, but under a certain combination of conditions, the impact of harmonics is enhanced, with damaging results.

4.2 Effect of Harmonics in Motors

Electric motors experience losses due to hysteresis and eddy currents set up in the iron core of the motor. These are proportional to the frequency of the current. Since the harmonics are at higher frequencies, they produce higher core losses in a motor than the power frequency would. This results in increased heating of the motor core, which (if excessive) can shorten the life of the motor. The 5th harmonic causes a CEMF (counter electromotive force) in

large motors which acts in the opposite direction of rotation. The CEMF is not large enough to counteract the rotation; however it does play a small role in the resulting rotating speed of the motor.

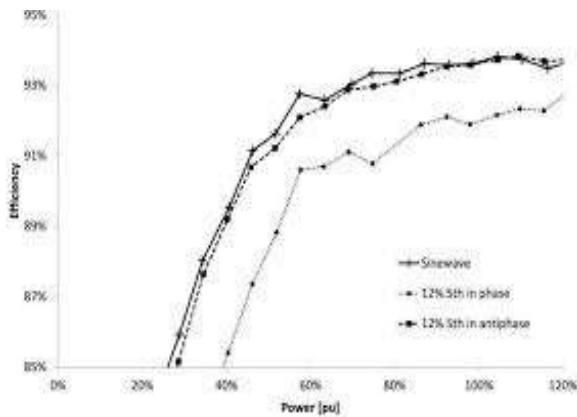
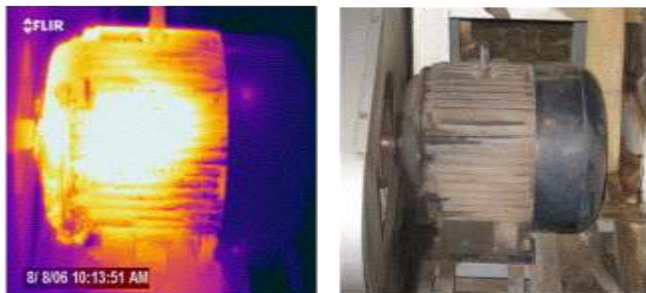


Fig .Effect of harmonics in motor



Above thermal and daylight images show a three phase motor which has overheated. Power quality analysis proved condition was caused by negative sequence harmonics.

4.3 Effect of Harmonics on Transformers

Harmonic problems in transformers occur from both core and copper losses caused by positive and negative sequence harmonic currents carried on phase conductors from single-phase and three-phase harmonic generating loads. Zero sequence harmonic currents carried on neutral conductors from harmonic generating equipment can also have an effect on transformers. Zero sequence harmonics mathematically add-up in the neutral conductor of three-phase four-wire systems and then pass through the distribution system until they reach a delta-wye transformer. When zero sequence harmonics caused by neutral currents reach a delta-wye transformer, they circulate in the delta primary winding causing shortened transformer life, due to increased heat



Above thermal image shows overheated windings on a step-down transformer, possibly caused by harmonics.

5. CONCLUSION

The ever increasing use of electronic equipment that uses switch mode power supplies, destructive harmonics in distribution systems will continue to grow. As previously described, properly designed distribution systems will help control the damaging effects of harmonic currents transformer, motor

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- [3] Power Quality in Power Systems and Electrical Machines 2nd Edition
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