AN OVERVIEW OF HARMONICS

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Introduction

This paper gives general awareness of power system harmonics, their causes, effects and methods to control them especially when these harmonics are related to variable frequency (or adjustable speed) drives. Some of the topics covered are: definitions, harmonic generation, effects of harmonics and control of harmonics.

General

A "linear" load connected to an electric power system is defined as a load which draws current from the supply which is proportional to the applied voltage (for example, resistive, incandescent lamps etc). An example of a voltage and current waveforms of a linear load is shown in Figure 1.

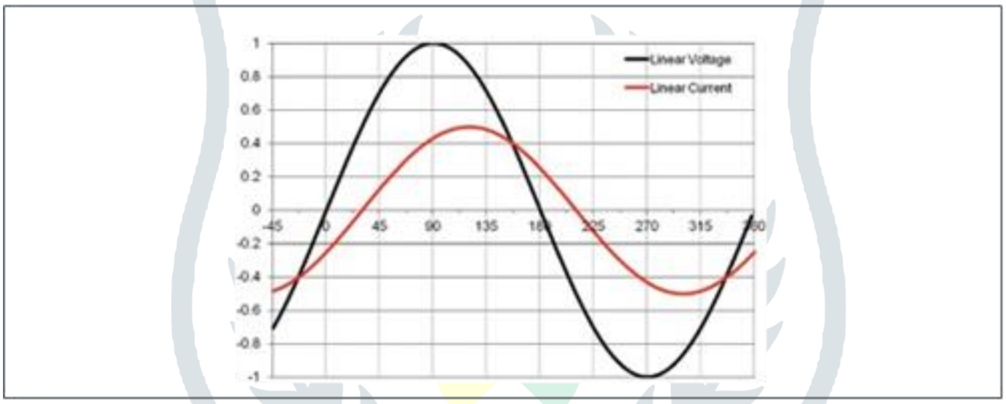

Figure 1Voltage and current of a linear load

A load is considered "non-linear" if its impedance changes with the applied voltage. Due to this changing impedance, the current drawn by the non-linear load is also non-linear i.e. non-sinusoidal in nature, even when it is connected to a sinusoidal voltage source (for example computers, variable frequency drives, discharge lighting etc). An example of a voltage and current waveforms of a non-linear load is shown in Figure 2. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads

Harmonic generation

Static power converters are the equipments that utilize power semiconductor devices for power conversion from AC to DC, DC to DC, DC to AC and AC to AC; and constitute the largest nonlinear loads connected to the electric power systems. These converters are used for various purposes in the industry, such as adjustable speed (or variable frequency) drives, uninterruptable power supplies, switch-mode power supplies etc. These static power converters used in a variety of applications draw non-linear (i.e. non-sinusoidal) currents and distort the supply voltage waveform at the point of common coupling (PCC). This phenomenon is explained here using Figure 3.1 and 3.2.

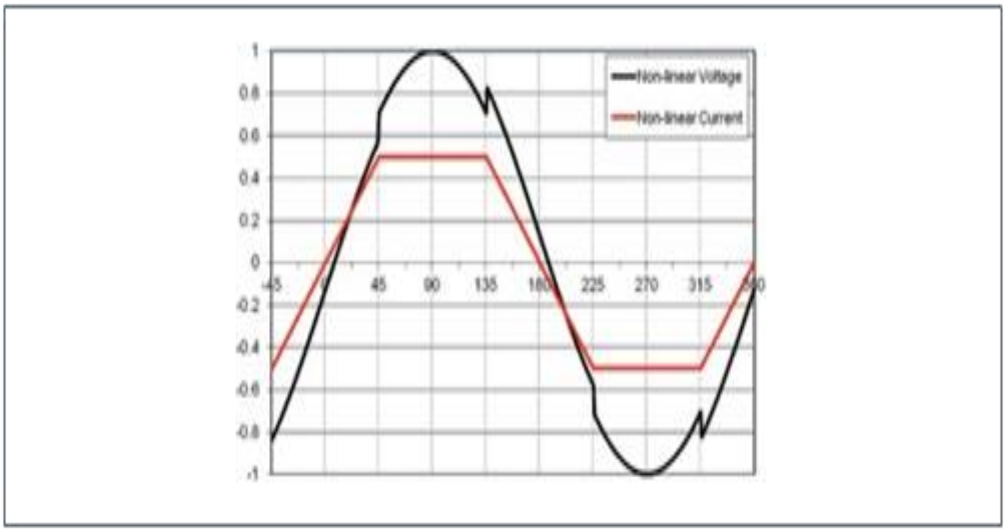

Figure 2

Voltage and current of a non-linear load

The PCC is a point between the system owner or operator and a user. The PCC is usually taken as the point in the power system closest to the user where the system owner or operator could offer service to another user. Frequently for service to industrial users (i.e., manufacturing plants) via a dedicated service transformer, the PCC is at the HV side of the transformer. For commercial users (i.e. office parks, shopping malls, etc.) supplied through a common service transformer, the PCC is commonly at the LV side of the service transformer. In general, The PCC is a point on a public power supply system, electrically

nearest to a particular load, at which other loads are, or could be connected and is located on the upstream of the considered installation.

Figure 3(a) shows the single-phase full wave diode bridge rectifier supplying a load containing an inductance (Ldc) and a resistance (Rdc). The impedance of the AC power supply is represented by the inductance (Lac).connected to it.

Figure 3(b) depicts the DC load current (idc) without ripple (i.e. assuming highly inductive load) and corresponding AC input current (iac) of this rectifier. A trapezoid shape of the AC current is due to the presence of finite AC line inductance and shows overlap (or commutation) period during which the two diodes are conducting thereby resulting in a transient short circuit through them. Ideally, if this AC line inductance is zero (i.e. an infinite source feeding the rectifier), the transition of the AC current is instantaneous and the current wave shape is rectangular

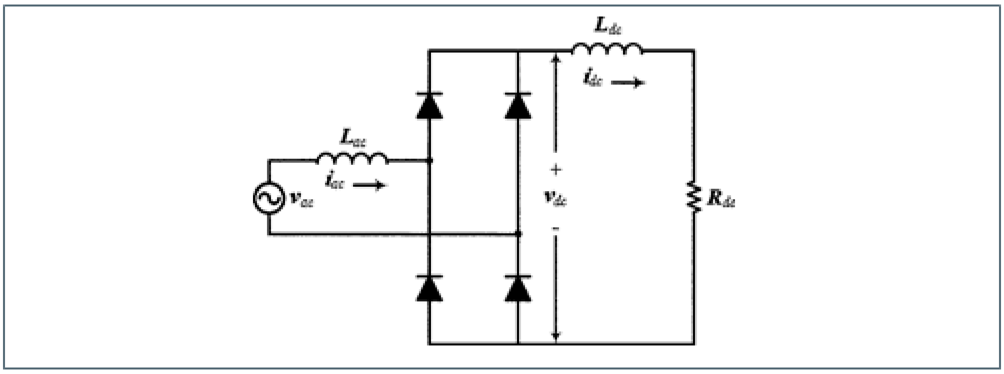

Figure 3(a)Single phase full wave rectifier

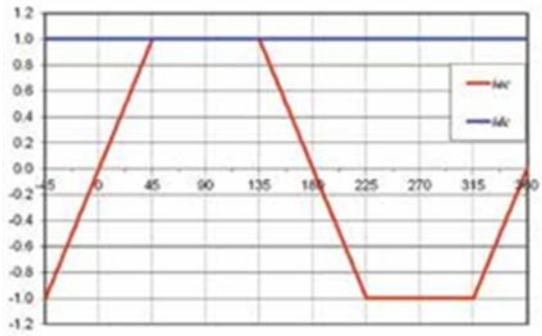

Figure 3(b) DC load current and AC supply current

Harmonic spectrum and distortion factor

Ideally, the harmonics produced by the semiconductor converter equipment in steady state condition of operation are called characteristic harmonics of the converter and are expressed as:

$h = np \pm 1$

where, h = order of harmonics

n = an integer 1, 2, 3,….

p = number of pulses per cycle

For a single phase bridge rectifier, the number of pulses p = 2 for one cycle of line frequency and therefore the characteristic harmonics are:

h = n .2 ± 1 = 1 (fundamental), 3 , 5 , 7 , 9 , 11 …..

These dominant or characteristic harmonics can be seen from Figure (3.3) (a harmonic spectrum) of the AC input current waveform of a single phase bridge rectifier.

For a three phase bridge rectifier, since the number of pulses p = 6 per line frequency cycle, the characteristic or dominant harmonics are:

h = n ·6 ± 1 = 5, 7, 11, 13, 17, 19, 23, 25, 35, 37…

Similarly, the characteristic harmonic currents for a 12-pulse rectifier will be:

h = n ·12 ± 1 = 11, 13, 23, 25, 35, 37…

Abovementioned characteristic harmonics are for an ideal steady state operation of the converter and assuming the AC power supply network is symmetrical and the AC supply is pure sinusoidal (free from harmonics). Any divergence from the abovementioned hypothesis will introduce "non-characteristic" harmonics including possibly DC component. In practical situation, the supply networks or connected equipments never follow the abovementioned ideal condition and therefore, the actual measured harmonics will not be exactly as calculated .

Moreover, it should be noted that in four-wire distribution systems (three-phase and neutral), the currents in the three phases return via the neutral conductor, the 120-degree phase shift between respective phase currents causes the currents to cancel out in the neutral, under balanced loading conditions. However, when nonlinear loads are present, any "Triplen" (3rd, 9th…) harmonics in the phase currents do not cancel out but add cumulatively in the neutral conductor, which can carry up to 173% of phase current at a frequency of predominately 180 Hz (3rd harmonic).

The amount of distortion in the voltage or current waveform is quantified by means of an index called the total harmonic distortion (THD). According to IEEE 519-1992, it is defined as a ratio of the root-mean-square of the harmonic content to the root-mean-square value of the fundamental quantity and expressed as a percent of the fundamental.

$$\%THD_{Vpcc} = \frac{\sqrt{\sum_{h=2}^{\infty} V_{pcch}^{2}}}{V_1} \times 100$$

Similarly, total harmonic distortion of current,

$$\%THD_I = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^{2}}}{I_1} \times 100$$

Typically, the harmonics up to the 50th order are used to calculate the %THD, however, the harmonic components of order greater than 50 may be included when necessary. Recommended values of voltage and current distortion according to IEEE 519-1992.

According to IEEE 519-1992, the total effect of distortion in the current waveform at the PCC is measured by the index called the total demand distortion (TDD), as a percentage of the maximum demand current at the PCC. In other words, it is defined as a ratio of the root mean square of the harmonic content, (considering harmonic components typically up to the 50th order) to the root-mean-square of the maximum demand load current at the PCC and expressed as a percentage of maximum demand load current .

Effects of harmonics

When a nonlinear load draws distorted (non-sinusoidal) current from the supply, which distorted current passes through all of the impedance between the load and power source. The associated harmonic currents passing through the system impedance cause voltage drops for each harmonic frequency based on Ohm’s Law.The vector sum of all the individual voltage drops results in total voltage distortion, the magnitude of which depends on the system impedance, available system fault current levels and the levels of harmonic currents at each harmonic frequency.

- High fault current (stiff system)
- Distribution system impedance and distortion is low
- Harmonic current draw is high
- Low fault current (soft system)
- Distribution system impedance and distortion is high
- Harmonic current draw is low

Conclusion

With increase in use of non-linear loads, the issues of power supply harmonics are more noticeable than ever. Controlling and monitoring industrial system designs and their effects on utility distribution systems are potential problems for the industrial consumer, who is responsible for complying with the IEEE 519, recommended practices and procedures.

Industrial facilities should include a system evaluation, including a harmonic distortion analysis, while planning facility construction or expansion. Vendors of non-linear loads, such as variable frequency drives, can provide services and recommend equipments that will reduce harmonics in order to comply with IEEE 519 guidelines.A particular type of harmonic mitigation solution can be used depending upon the application and desired level of attenuation to meet the limits given in IEEE 519.

References

[1] IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems, ANSI/IEEE Std. 519-1992.

[2] Industrial and Commercial Power Systems Analysis, ANSI/IEEE Std. 399-1990.

[3] Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converter, Applications and Design, Wiley, 3rd edition, 2002.

[4] Kevin lee, Derek A. Paice and James E. Armes, “The Wind Mill Topology - Evaluation of Adjustable Speed Drive Systems”, IEEE IAS Magazine, Mar/Apr 2009.

[5] ABS Guidance Notes on Control of Harmonics in Electrical Power Systems, American Bureau of Shipping, 2006

[6] Electric Power Distribution for Industrial Plants, ANSI/IEEE Std. 141-1986.

[7] IEEE Guide for Application and Specification of Harmonic Filters, IEEE Std 1531-2003.