Harmonics in Electrical Systems

One of the biggest problems in power quality aspects is the harmonic contents in the electrical system. Generally, harmonics may be divided into two types:

1) Voltage harmonics, and

2) Current harmonics.

Current harmonics is usually generated by harmonics contained in voltage supply and depends on the type of load such as resistive load, capacitive load, and inductive load. Both harmonics

can be generated by either the source or the load side. Harmonics generated by load are caused by nonlinear operation of devices, including power converters, arc-furnaces, gas discharge lighting devices, etc.

Load harmonics can cause the overheating of the magnetic cores of transformer and motors. On the other hand, source harmonics are mainly generated by power supply with non-sinusoidal voltage waveform. Voltage and current source harmonics imply power losses, Electromagnetic Interference (EMI) and pulsating torque in AC motor drives. Any periodic waveform can be shown to be the superposition of a fundamental and a set of harmonic components. By applying Fourier transformation, these components can be extracted. The frequency of each harmonic component is an integral multiple of its fundamental. There are several methods to indicate of the quantity of harmonics contents.

The most widely used measurement is the total harmonics distortion (THD), which is defined in terms of the amplitudes of the harmonics, H_n, at frequency nw_0,

where

w_0 is frequency of the fundamental component whose amplitude of H_1 and

n is integer.

The THD is mathematically given by

$$THD = \frac{\sqrt{\sum_{n=2}^{\infty} H_{(n)}^{2}}}{H_1}$$

4.11 Harmonic Limits

Voltage and Current Harmonic Limits

According to IEEE Std. 519, harmonic voltage distortion on power systems 69 kV and below is limited to 5% total harmonic distortion (THD) with each individual harmonic limited to 3%. The current harmonic limits vary based on the short-circuit strength of the system into which they are being injected. Essentially, the more the system is able to handle harmonic currents, the more the customer is allowed to inject.

Table 1 shows the IEEE 519 harmonic voltage limits, while Table 2 shows the harmonic current limits.

TABLE 1. IEEE STD 519-1992 HARMONIC VOLTAGE LIMITS VOLTAGE DISTORTION LIMITS.

Bus Voltage at PCC	Individual Voltage Distortion (%)	Distortion THD (%) Total Voltage
69 kV and below	3.0	5.0
69.001–161 kV	1.5	2.5
161.001 kV and above	1.0	1.5

NOTE: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

TABLE 2. IEEE STD 519-1992 HARMONIC CURRENT LIMITS

CURRENT DISTORTION LIMITS FOR GENERAL DISTRIBUTION SYSTEMS (120–69,000 V) .

I_{SC}/I_L	Maximum Harmonic Current Distortion in Percent of I_L Individual Harmonic Order (Odd Harmonics)					
	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g. half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual Isc/IL.

Where

I_{SC} = maximum short-circuit current at PCC.

I_L = maximum demand load current (fundamental frequency component) at PCC.

TDD = Total demand distortion (RSS), harmonic current distortion in % of maximum demand load current (15 or 30 min demand).

PCC = Point of common coupling.

The harmonic current limits specify the maximum amount of harmonic current that the customer can inject into the utility system. The utility is responsible for providing a clean (low distortion) voltage to the customer. The utility can only be fairly judged, however, when the customer meets the harmonic current limits. Otherwise, the customer may be guilty of causing the voltage distortion himself.

The intent of IEEE 519 is stated in its Forward

–*This recommended practice recognizes the responsibility that users have not to degrade the voltage of the utility serving other users by requiring nonlinear currents from the utility. It also recognizes the responsibility of the utilities to provide users with close to a sine wave of voltage.*‖

Section 10.2 of IEEE 519 goes on to say:

The philosophy of developing harmonic limits in this recommended practice is to

⊞ Limit the harmonic injection from individual customers so that they will not cause unacceptable voltage distortion levels for normal system characteristics

⊞ Limit the overall harmonic distortion of the system voltage supplied by the utility.

These limits are intended to be applied at the point of common coupling (PCC) between the customer and the utility. Within the customer's facility these limits do not apply, but they are still useful guides for judging harmonic levels within the customer's facility.