Harmonic evaluation for end-user facilities

Harmonic problems are more common at end-user facilities than on the utility supply system. Most nonlinear loads are located within end-user facilities, and the highest voltage distortion levels occur close to harmonic sources. The most significant problems occur when there are nonlinear loads and power factor correction capacitors that result in resonant conditions. IEEE Standard 519-1992 establishes harmonic current distortion limits at the PCC. The limits, summarized in Table 6.2, are dependent on the customer load in relation to the system short-circuit capacity at the PCC.

The variables and additional restrictions to the limits given in Table 6.2 are

TABLE 6.2 Harmonic Current Distortion Limits (I_h) in Percent of I_L

$V_n \leq 69$ kV						
I_{SC}/I_L	$h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	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
69 kV $< V_n \leq$ 161 kV						
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20–50	3.5	1.75	1.25	0.5	0.25	4.0
50–100	5.0	2.25	2.0	0.75	0.35	6.0
100–1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0
$V_n > 161$ kV						
<50	2.0	1.0	0.75	0.3	0.15	2.5
≥50	3.0	1.50	1.15	0.45	0.22	3.75

- I_h is the magnitude of individual harmonic components (rms amps).
- I_{SC} is the short-circuit current at the PCC.
- I_L is the fundamental component of the maximum demand load current at the PCC. It can be calculated as the average of the maximum monthly demand currents for the previous 12 months or it may have to be estimated.
- The individual harmonic component limits apply to the odd-harmonic components. Even harmonic components are limited to 25 percent of the limits.
- Current distortion which results in a dc offset at the PCC is not allowed.
- The total demand distortion (TDD) is expressed in terms of the maximum demand load current, i.e.,

$$\text{TDD} = \frac{\sqrt{\sum_{2} I_h^2}}{I_L} \times 100\%$$

If the harmonic-producing loads consist of power converters with pulse number q higher than 6, the limits indicated in Table 6.2 are increased by a factor equal to $\sqrt{q/6}$

In computing the short-circuit current at the PCC, the normal system conditions that result in minimum short-circuit capacity at the PCC should be used since this condition results in the most severe system impacts.

A procedure to determine the short-circuit ratio is as follows

1. Determine the three phases short-circuit duty *I*SC at the PCC. This value may be obtained directly from the utility and expressed in amperes. If the short circuit duty is given in mega volt amperes, convert it to an amperage value using the following expression

$$\mathrm{I_{SC}} = \frac{1000 \times \mathrm{MVA}}{\sqrt{3}\,\mathrm{kV}} \qquad \mathrm{A}$$

where MVA and kV represent the three-phase short-circuit capacity in mega volt amperes and the line-to-line voltage at the PCC in kV, respectively.

2. Find the load average kilowatt demand *PD* over the most recent 12 months. This can be found from billing information.

3. Convert the average kilowatt demand to the average demand current in amperes using the following expression

$$I_L = \frac{\mathrm{kW}}{\mathrm{PF}\ \ \sqrt{3}\ \ \mathrm{kV}} \qquad \mathrm{A}$$

where *PF* is the average billed power factor.

4. The short-circuit ratio is now determined by:

$$\text{Short-circuit ratio} = \frac{I_{\mathrm{SC}}}{I_L}$$

This is the short-circuit ratio used to determine the limits on harmonic currents in IEEE Standard 519-1992. In some instances, the average of the maximum demand load current at the PCC for the previous 12 months is not available. In such circumstances, this value must be estimated based on the predicted load profiles. For seasonal loads, the average should be over the maximum loads only.

Current limit evaluation procedure

This procedure involves evaluation of the harmonic generation characteristics from individual end user loads with respect to IEEE Standard 519-1992 limits. However, special consideration is required when considering power factor correction equipment.

1. Define the PCC. For industrial and commercial end users, the PCC is usually at the primary side of a service transformer supplying the facility.
2. Calculate the short-circuit ratio at the PCC and find the corresponding limits on individual harmonics and on the TDD.
3. Characterize the harmonic sources. Individual nonlinear loads in the facility combine to form the overall level of harmonic current generation.

The best way to characterize harmonic current in an existing facility is to perform measurements at the PCC over a period of time (at least 1 week). For planning studies, the harmonic current can be estimated knowing the characteristics of individual nonlinear loads and the percentage of the total load made up by these nonlinear loads. Typical characteristics of individual harmonic sources were presented in Secs. 5.6 and 5.7.

4. Evaluate harmonic current levels with respect to current limits using Table 6.2. If these values exceed limits, the facility does not meet the limit recommended by IEEE Standard 519-1992 and mitigation may be required.

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