A Review of Harmonic Distortion

Harmonic distortion (HD) can affect the operation of electrical equipment. For example, it can generate additional heating in induction motors, transformers and capacitors and cause accelerated degradation of insulation and reduce anticipated functional life.

HARMONIC DISTORTION

Ideally voltage and current in a power system are of a single frequency (Power Frequency [1]), and represented by (1)

$$H(t) = \sqrt{2}H_{rms}sin(\omega t + \theta_H), \qquad H = V, I \ldots (1)$$

Electronic devices distort the waveshapes in (1) and hence can introduce undesirable higher order frequency components called harmonics. The total waveform is now composed of the Power Frequency (also called fundamental frequency), together with the undesirable harmonics and represented by (2).

$$H(t) = \sqrt{2}\sum_{n=1}^{n=N} H_n sin(n\omega t + n\theta_H), \qquad H = V, I \ \ldots (2)$$

HD is a figure of merit and defined in (3) as the ratio of the amplitude of a single harmonic to the amplitude of the fundamental expressed as a percentage.

$$HD_n(\%) = \frac{H_n}{H_1} \times 100 \ldots (3)$$

Practically, the Total Harmonic Distortion (THD) is much more useful as it considers all harmonics and is measured by the ratio of the harmonic amplitude to the fundamental expressed as a percentage (4).

$$HD(\%) = THD_F(\%) = \frac{\sqrt{H_2^2 + H_n^2 + \cdots + H_N^2}}{H_1} \times 100 \ldots (4)$$

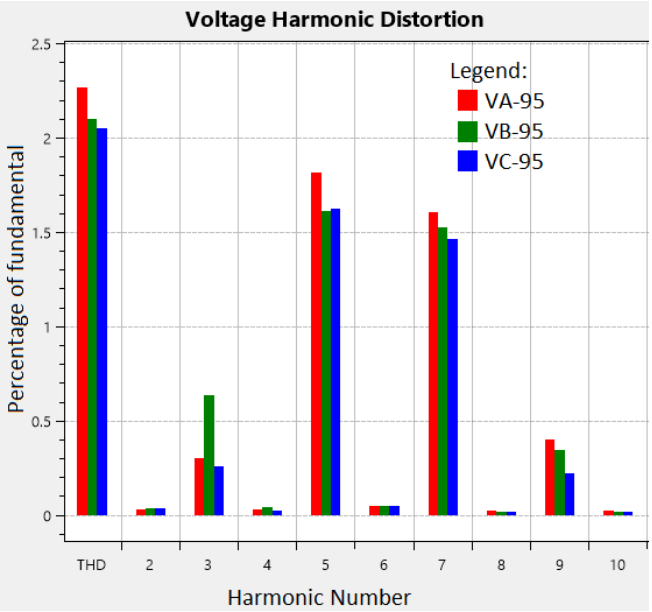

Figure 1 *Example datafile showing voltage HD and THD*

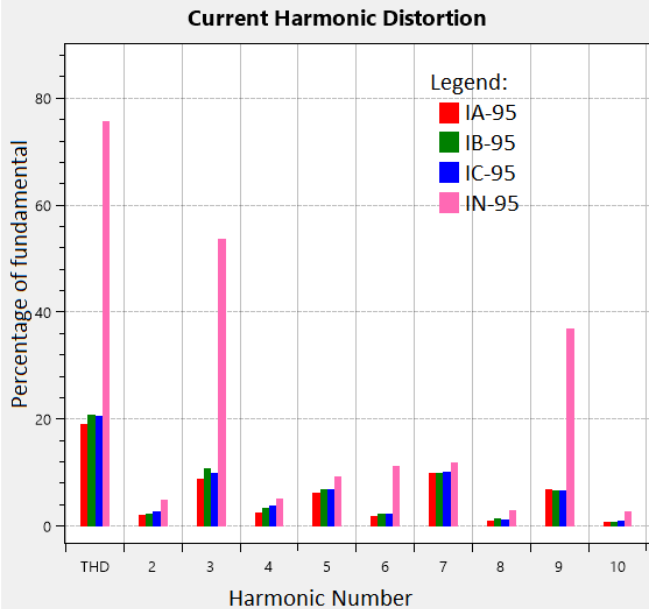

Figure 2 *Example datafile showing current HD and THD*

DATAFILE EXAMPLES

Following a Power Quality investigation of a three-phase system at a customer site by CHK PQ, Figures 1 and 2 show HD and THD for voltage and current at the 95 percentiles (up to the 10th harmonic only for illustration). The maximum voltage and current THD reached 2.3% (Red phase, Figure 1) and (75.1%, 20.1%, Figure 2) for Neutral and Green phase respectively.

Typically, voltage THD (VTHD,) usually lies between 2% to 5% whilst current THD (ITHD) can vary significantly and is usually much higher than VTHD.

RELATED METRICS

THD can also be defined as a ratio of harmonic amplitude to the RMS expressed as a percentage (5) with range of 0≤ THD_R (%)<100%.

$$THD_R(\%) = \frac{\sqrt{H_2^2 + H_n^2 + \cdots + H_N^2}}{H_{rms}} \times 100 \quad \ldots (5)$$

THD_F and THD_R are approximately the same for the case where the RMS value is dominated by the fundamental amplitude.

References

[1] AS/NZS 61000.4.30:2012, Electromagnetic compatibility (EMC) Part 4.30: Testing and measurement techniques - Power quality measurement methods.