4 Main effects of harmonics in installations

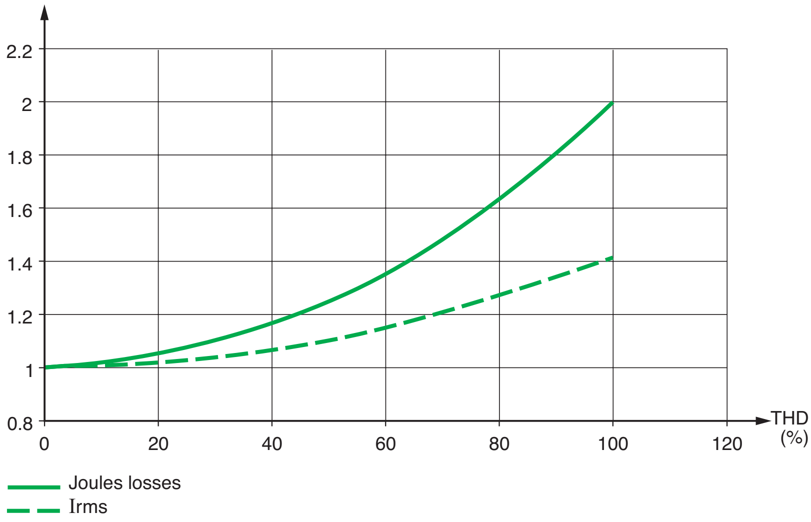

Fig. M8 : Increase in rms current and Joule losses as a function of the THD

Orders of magnitude

- A virtually rectangular supply voltage provokes a **20% increase** in losses
- A supply voltage with harmonics u5 = 8% (of U1, the fundamental voltage), u7 = 5%, u11 = 3%, u13 = 1%, i.e. total harmonic distortion THDu equal to 10%, results in additional losses of 6%

Losses in transformers

Harmonic currents flowing in transformers provoke an increase in the "copper" losses due to the Joule effect and increased "iron" losses due to eddy currents. The harmonic voltages are responsible for "iron" losses due to hysteresis.

It is generally considered that losses in windings increase as the square of the THDi and that core losses increase linearly with the THDu.

In utility-distribution transformers, where distortion levels are limited, losses increase between 10 and 15%.

Losses in capacitors

The harmonic voltages applied to capacitors provoke the flow of currents proportional to the frequency of the harmonics. These currents cause additional losses.

Example

A supply voltage has the following harmonics:
Fundamental voltage U1, harmonic voltages u5 = 8% (of U1), u7 = 5%, u11 = 3%, u13 = 1%, i.e. total harmonic distortion THDu equal to 10%. The amperage of the current is multiplied by 1.19. Joule losses are multiplied by 1.19^2, i.e. 1.4.

4.3 Overloads on equipment

Generators

Generators supplying non-linear loads must be derated due to the additional losses caused by harmonic currents.

The level of derating is approximately 10% for a generator where the overall load is made up of 30% of non-linear loads. It is therefore necessary to oversize the generator.

Uninterruptible power systems (UPS)

The current drawn by computer systems has a very high crest factor. A UPS sized taking into account exclusively the rms current may not be capable of supplying the necessary peak current and may be overloaded.

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Transformers

■ The curve presented below (see **Fig. M9**) shows the typical derating required for a transformer supplying electronic loads

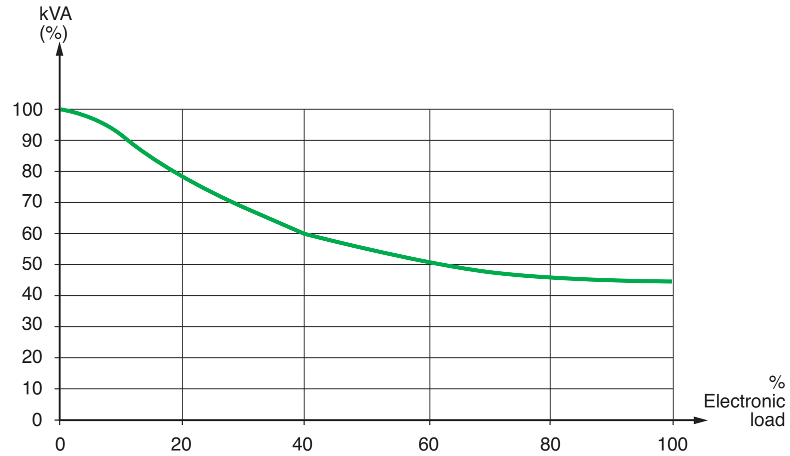

Fig. M9 : Derating required for a transformer supplying electronic loads

Example

If the transformer supplies an overall load comprising 40% of electronic loads, it must be derated by 40%.

■ Standard UTE C15-112 provides a derating factor for transformers as a function of the harmonic currents.

$$k = \frac{1}{\sqrt{1 + 0.1\left(\sum_{h=2}^{40} h^{1.6}\, T_h^2\right)}}$$

$$T_h = \frac{I_h}{I_1}$$

Typical values:

■ Current with a rectangular waveform (1/h spectrum [(1)]): k = 0.86

■ Frequency-converter current (THD ≈ 50%): k = 0.80

Asynchronous machines

Standard IEC 60892 defines a weighted harmonic factor (Harmonic voltage factor) for which the equation and maximum value are provided below.

$$HVF = \sqrt{\sum_{h=2}^{13} \frac{U_h}{h^2}} \leqslant 0.02$$

Example

A supply voltage has a fundamental voltage U1 and harmonic voltages u3 = 2% of U1, u5 = 3%, u7 = 1%. The THDu is 3.7% and the MVF is 0.018. The MVF value is very close to the maximum value above which the machine must be derated. Practically speaking, for supply to the machine, a THDu of 10% must not be exceeded.

Capacitors

According to IEC 60831-1 standard, the rms current flowing in the capacitors must not exceed 1.3 times the rated current.

Using the example mentioned above, the fundamental voltage U1, harmonic voltages u5 = 8% (of U1), u7 = 5%, u11 = 3%, u13 = 1%, i.e. total harmonic distortion THDu equal to 10%, the result is $\frac{Irms}{I1} = 1.19$, at the rated voltage. For a voltage equal to 1.1 times the rated voltage, the current limit $\frac{Irms}{I1} = 1.3$ is reached and it is necessary to resize the capacitors.

(1) In fact, the current waveform is similar to a rectangular waveform. This is the case for all current rectifiers (three-phase rectifiers, induction furnaces).