K-Factor Transformers

In recent years, there has been a steep rise in the number of non-linear loads connected to the electrical power network: computers, fax machines, discharge lamps, arc furnaces, battery chargers, UPS systems, electronic power supplies, etc.

The consequences for the electrical power system are becoming a cause for concern due to the increasing use of such equipment, combined with the application of electronics to virtually every electrical load. Non-linear loads draw considerable distorted current which can be decomposed into harmonics.

In order to protect transformers against overheating due to these harmonics, manufacturers may specify derated equipment, i.e. oversized transformers which can operate at a fraction of their rated capacity.

What is the K-Factor?

The K-Factor indicates the amount of heat produced by sinusoidal currents compared with the same rms value of a pure sine current.
The K-Factor, which provides a measurement of the thermal effects on transformers, is defined by the ANSI/IEEE C57.110 standard.
A K-Factor of 1.0 corresponds to a linear load (with no harmonics). The higher the K-Factor, the greater the overheating caused by the harmonics.

There are not currently any standards imposing calculation methods for the K-Factor, but two formulae are widely used:

$$K-Factor=\frac{\sum_{n=1}^{n=\infty} I_n^2 \tau_n^2}{\sum_{n=1}^{n=\infty} \tau_n^2}$$

where τ *is the partial rate of each order*

This K-Factor can then be compared with the transformer's nameplate value.

Example: a measured K-Factor of 12 should be compared with (and must remain lower than) the factor specified by the transformer manufacturer.

$$K-Factor=\left[1+\frac{e}{1+e}\left(\frac{I_1}{I}\right)^2 \sum_{n+2}^{n=N}\left(n^q\left(\frac{I_n}{I_1}\right)^2\right)\right]^{0,5}$$

where e *is the ratio between the hysteresis loss and the total load losses,*
n *is the order of the harmonic*
and q *is a typical exponential coefficient*

This K-Factor indicates the transformer's current "harmonic load" percentage.

Example: a measured K-Factor of 0.77 indicates that the transformer in question is operating at 77 % of its load capacity.

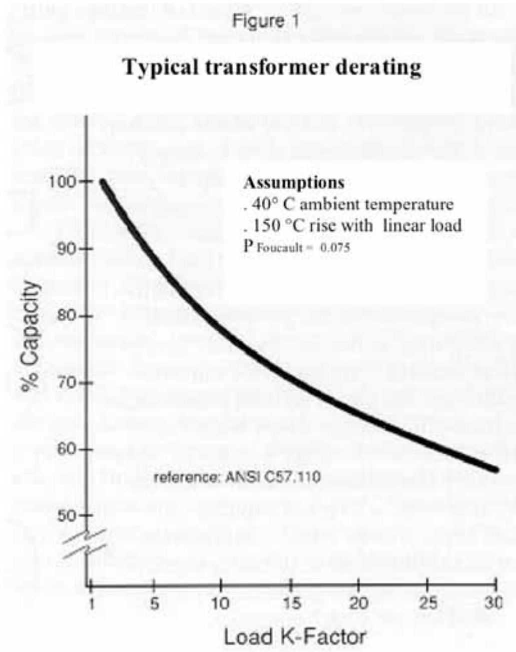
At the transformer end…

A magnetic field known as leakage flux is present in transformer windings. This flux induces currents causing 1 to 10 % of the Joule-effect losses in a sinusoidal system. In a distorted system, these losses may be 20 times higher.
In such cases, the transformer's temperature rises and may exceed the thermal capacity of the insulants, leading to failure of the transformer. In addition, harmonics induce a high current on the neutral of the transformer's secondary winding.

To protect transformers, designers may specify **"derated" equipment**, i.e. oversized transformers running at a fraction of their rated capacity, or **K-Factor transformers** specially designed for harmonic currents.

K-Factor transformers are usually chosen because they have a higher thermal capacity with known limits. They are designed to minimize the losses caused by harmonic currents and their neutral and terminal connections are sized at 200 % of normal.
Another good reason for this choice is cost: a K-Factor transformer is cheaper than an oversized transformer.
The choice of the transformer then depends on the K-Factor of the loads present on the electrical power network.

Example:
In areas with high concentrations of computers and single-phase terminals, K-Factors ranging from 13 to 20 may be encountered. If so, the transformer must have a K-Factor of at least 20.



This figure shows a typical derating curve as defined by the ANSI/IEEE C57.110 standard.

Chauvin Arnoux® instruments for K-factor calculation

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