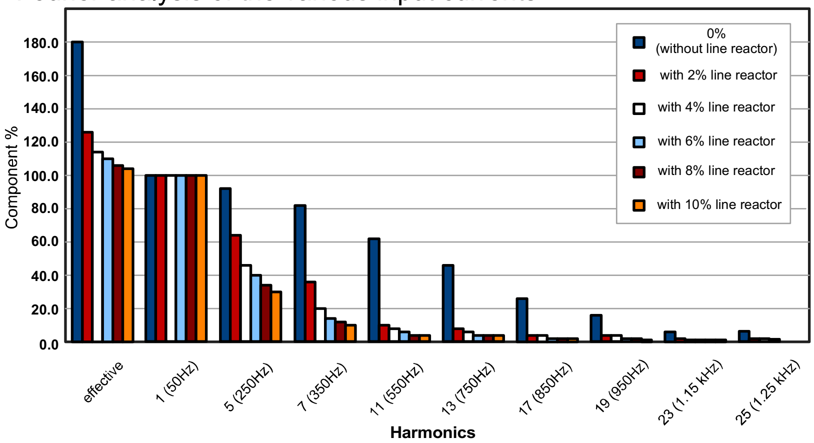
The effect of line reactors on mains harmonics

In technical publications a short-circuit voltage of 2% and 4% is always specified for line reactors. The installer has to ask himself the following questions:-

- How does the choke inductance affect harmonics?
- Which choke is best for my equipment and will it create the lowest losses ?
- Will I conform with harmonic regulations?

For the purpose of this investigation an inverter rated for 5 kW, with a 6-pulse uncontrolled rectifier on the input side and capacitors in the DC link, was used. The output semi-conductors switched at 4 Khz over a 50m length of cable to the asynchronous motor. DC injection braking was used to ensure equal excitation for all chokes.

Firstly, the input current and power were measured and then the armature current and voltage. Then line reactors with 2, 4, 6, 8 and 10% values were connected before the inverter. The following bar chart shows the Fourier analysis of the various input currents.



The 50 Hz current is used as a reference for assessing the harmonics in the bar chart, this alone delivers the useful power for the asychronous motor. It clearly demonstrates the reduction of the harmonics and the total effective (rms) current for each line reactor. A steady increase in the reactor's inductance results in a greater reduction of the harmonic content.The fifth harmonic accounts for the worst distortion.

The following table shows the 5th harmonic component for the corresponding line reactor:-

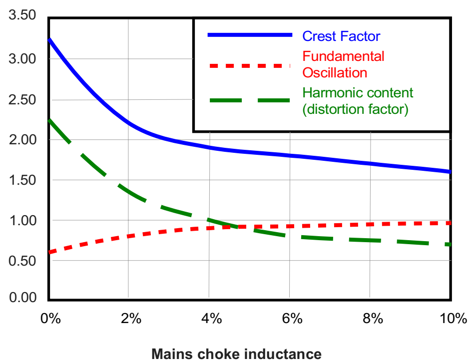
Line reactor value	none	2%	4%	6%	8%	10%
Portion of total RMS value	52%	50%	40%	36%	32%	29%

There are three factors used for evaluating harmonics:-

Crest factor: The ratio of peak to rms current.

Fundamental oscillation: The ratio of rms value of the fundamental oscillation to alternating current.

Harmonic content: The ratio of rms value of the harmonics to the rms value of the alternating current.



The diagram shows an analysis of these three values.
The 2% and 4% line reactors show a clear measurable improvement, whilst the 6%, 8% and 10% show very little.
A further consideration is the power balance, caused by the voltage drop from the reactor, for the 50 Hz useful current, which is little affected by power factor. Every inductor has copper and iron losses.

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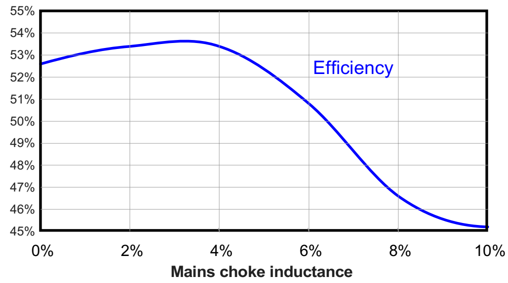
The following table shows the power losses before the inverter.

	none	2%	4%	6%	8%	10%
Volts drop across choke (50Hz)	0V	4.6V	9.2V	13.8V	18.4V	23V
Useful power (kW)	2.83	2.79	2.79	2.90	3.07	3.10
Latent choke losses (Watts)	0.0	0.84	2.61	5.31	10.27	15.74
Harmonic distortion losses (kW)	2.29	0.69	0.37	0.24	0.19	0.15
Total power (kW)	5.12	3.38	3.16	3.14	3.27	3.27

On the opposite side of the equation is the power used by a generator and resistor load.

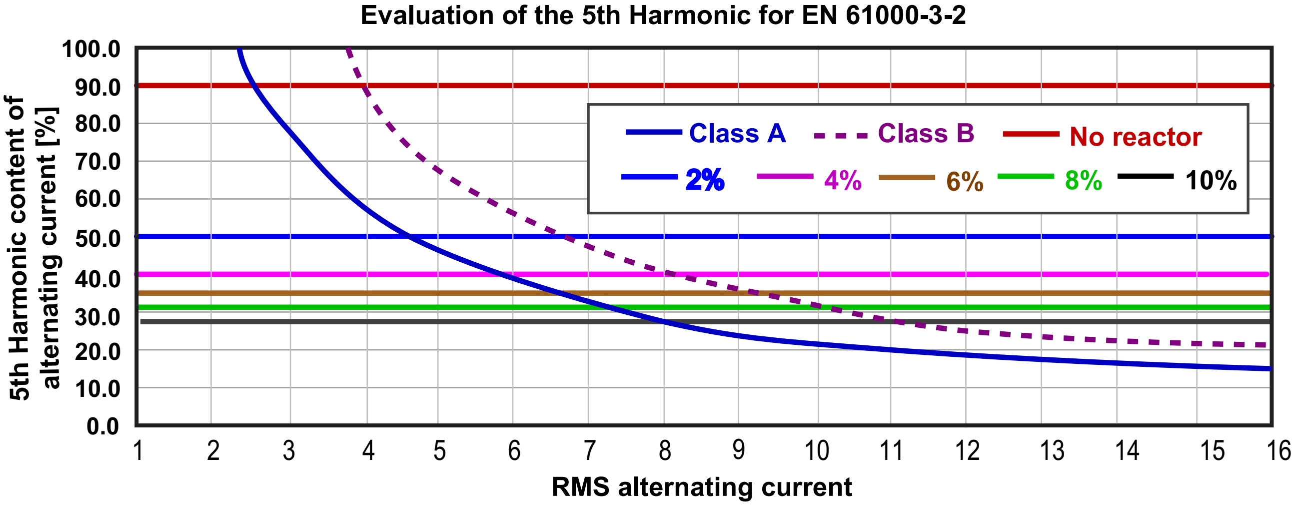
	none	2%	4%	6%	8%	10%
Output Power (kW)	1.49	1.49	1.49	1.47	1.43	1.40

The total efficiency can be calculated for the complete system and this provides the following curve:-



This shows the influence of the reactor on total system efficiency. It clearly demonstrates that the installation of a 2% or 4% reactor is meaningful. However, a greater inductance produces a marked deterioration in efficiency.

Finally, there is the question of whether harmonic levels are within the limits set by EN 61000-3-2. The following diagram is used for this purpose:-



It can be seen from this diagram that a line reactor is not required for a current draw of less than 2.5A. A 2% reactor is required for units connected to the mains supply with a current draw of up to 4.5A and 4% with a current of 5.6A etc.

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