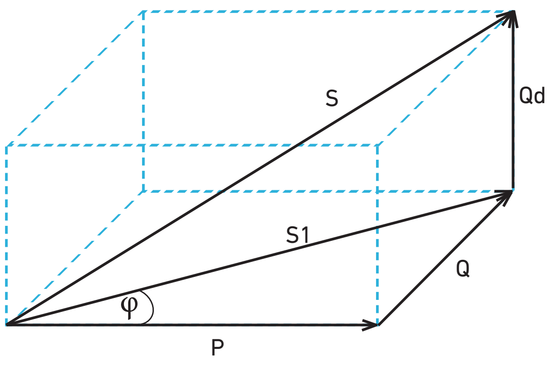
Höcherl & Hackl
The electronic load

Application Note #8

Non-Linear AC Loads with ACL Series

Frequently the requirement arises to apply non-linear loads to alternating voltages.
The terms cos phi, crest factor, power factor, displacement and distortion reactive power, among others, are used in this context, which we explain here.
We demonstrate by means of examples what is possible and what is not possible with electronic loads of the ACL series.



Terminology

Power Factor λ (PF)

A power factor is always determined if the multiplication of the measurement of voltage and current does not result in the actual active power P, but in an apparent power S. The power factor is valid for sinusoidal signals as well as other signal forms.

$$\lambda = P / S$$

cos φ

The cos φ is a special form of the power factor, which only applies when sinusoidal signals are present, as with inductive and capacitive loads.

Crest Factor CF

The crest factor is the ratio of the peak value to the RMS value of a waveform shape. A sinusoidal waveform has a crest factor of 1.41.

Reactive Power, Displacement Reactive Power Q

If current and voltage are out of phase we speak of reactive power, in the case of purely sinusoidal signals also of displacement reactive power.

Distortion Power, Deformed Power Qd

If the reactive power is not sinusoidal, it is called distortion or deformed power.

Apparent Power S

The apparent power is defined by the RMS values of current and voltage and is composed of active power P, displacement reactive power Q and distortion reactive power Qd:

$$S = U \cdot I = \sqrt{P^2 + Q^2 + Qd^2}$$

Voltage and Current Characteristics With Non-Linear Loads

In order to be able to evaluate which loads are possible with an electronic AC load and which are not, it is useful to consider some load cases.
For this purpose, special attention is paid to the direction of the power flow.

Principle of Electronic AC Loads

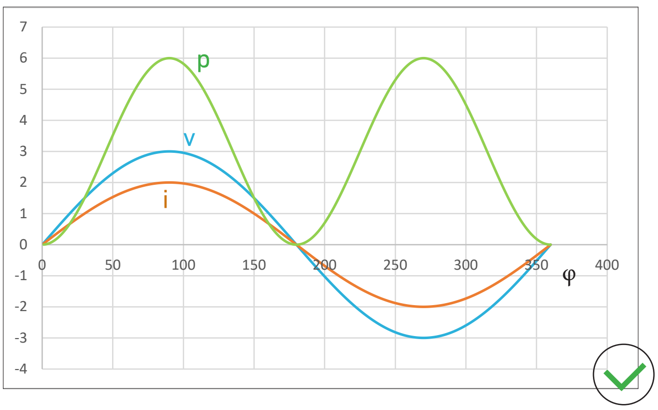
Electronic AC loads function basically like DC loads with preceding rectifier. However, the control voltage for setting the load is not a static signal as with direct current, but dynamic according to the rectified input voltage. Thus a sinusoidal alternating current is generated upstream of the rectifier.
Due to the rectifier, the energy flow of alternating current loads can thus only be in the direction of the load and never backwards in the direction of the source.

Inductive und Capacitive Loads

Since the electronic load can only absorb power, but cannot supply power, inductive or capacitive loads cannot be used without distorting the sinusoidal shape. This means that the sinusoidal waveform of the load current must be distorted by a phase cut or a crest factor > 1.41 so that the resulting power is positive at all times. In such cases the reactive power is therefore always a distortion reactive power.

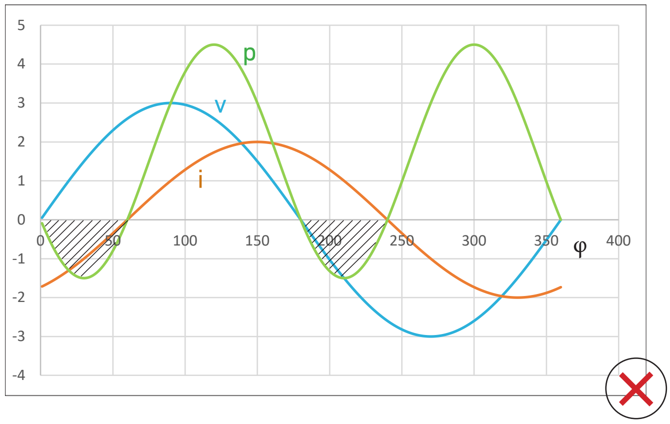
Example 1: Ohmic Load

CF = 1.41, phi = 0°
Current and voltage are in phase. The power is positive at all times. The load can simulate this case (typical application).



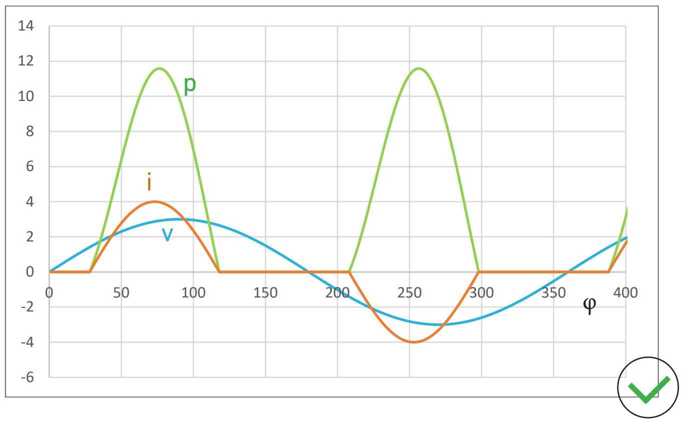
Example 2:

CF = 1.41, phi = 60°
Current and voltage are shifted in phase. There are significant areas where the performance goes into the negative. The load cannot reproduce this case.



Example 3:

CF = 2.0, phi = -30°
Current and voltage are not in phase. Due to the higher crest factor there are no areas with negative power. The load can simulate this case.



Result:

With electronic AC loads, phase shifts are always only possible in combination with phase cutting or setting the crest factor to values >1.41.
The larger the phase cut or the crest factor (the slimmer the current pulse), the further the phase can be shifted.
Phase shifts with sinusoidal currents as with inductive or capacitive loads are not possible, since a phase angle deviating from 0° would require a feedback into the source.

Rev. 03