

## QUESTION:

What is the difference between cosine phi and the power factor?

Is it not the same? Because  $S \cdot \cos \varphi = P$  and  $P^2 + Q^2 = S^2$ , so is also valid  $P/S = PF = \lambda = \cos \varphi$  - or isn't it?

## ANSWER:

The formula  $S \cdot \cos \varphi = P$  is only valid with sinusoidal values. However, in today's systems at least the current is far away from being sinusoidal. The " $\varphi$ " is the phase angle between the fundamental waves of current and voltage.

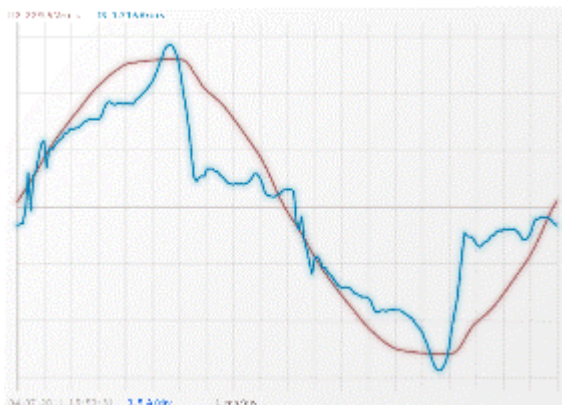
If there are also some harmonics included, the signal shape in the systems can be expressed by a sum of fundamental waves and integer harmonics. So the calculation becomes simpler and active power can be expressed as:

$$P = \sum (U_v \cdot I_v \cdot \cos \varphi_v)$$

With:  $v$  = harmonics,  $U_v$  = RMS of the  $v$ .th harmonic of  $U$ ,  $I_v$  also  $U_v$ .

A simple experiment:

Sinusoidal voltage and distorted current as seen here:



It is a real picture of line power. Voltage is sinusoidal, but not current. It is also easy to see that the fundamental waves of voltage and current almost have unity phase.

Because the voltage is sinusoidal,  $U_v = 0$  V for  $v > 1$ , it means that only on the fundamental components contribute to the RMS value (230 V) and also to the active power.

Result:  $P = U \cdot I_1 \cdot \cos \varphi_1$ . With this the above equation reduces to the fundamental components (the product would be 0 for all  $v > 1$ ).

Furthermore the (fundamental displacement) reactive power  $Q_1 = 0$ , because there is no phase shift between  $U$  and  $I$ .

The apparent power is defined as:

$$S = U_{\text{rms}} \cdot I_{\text{rms}} = (\sum (U_v^2))^{0,5} \cdot (\sum (I_v^2))^{0,5}$$

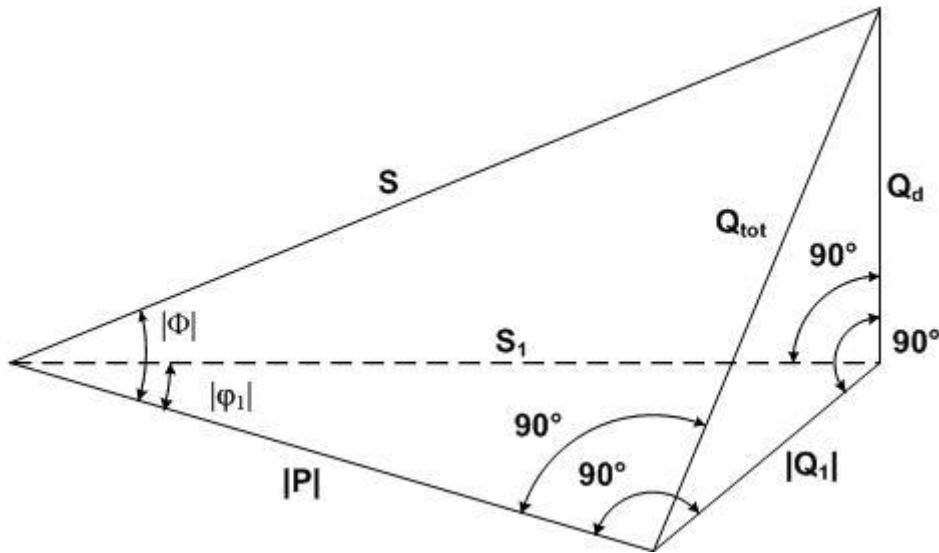
Because the current is considerable distorted  $I_v \neq 0$  for  $v > 1$ !

For this reason  $S > P$  and the power factor  $\lambda = P/S \neq \cos \varphi$ .

So, the power triangle is a 3-dimensional polyhedron or a universal triangular:

$$S^2 = P^2 + Q_1^2 + Q_d^2$$

- $Q_{tot}$  = Total reactive power
- $Q_1$  = Fundamental displacement reactive power
- $Q_d$  = Distortion reactive power (often also referred with "D")



$\cos \varphi$  results from the ratio of effective power ( $P$ ) to fundamental apparent power ( $S_1$ ).  
 Power factor  $\lambda = \cos \Phi$  results from the ratio of effective power ( $P$ ) to total apparent power ( $S$ ) from fundamental and harmonics.