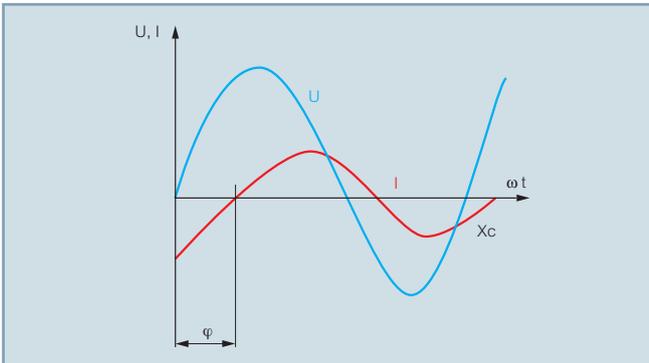


Power factor

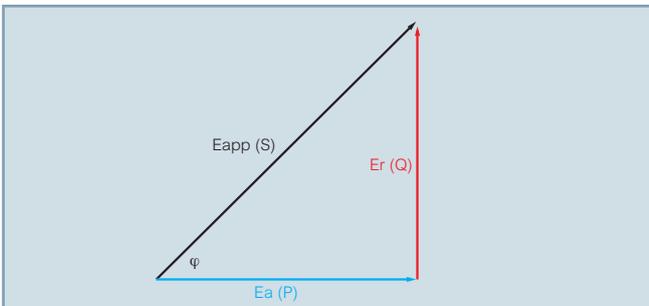
PHASE SHIFT - ENERGIES - POWERS

> Definition

An AC electrical installation comprising receivers such as transformers, motors, welding machines, power electronics, etc., and in particular any receivers for which the current is out of phase with the voltage, consumes a total energy which is called the apparent energy (E_{app}).



This energy, which is generally expressed in kilovolt-ampere-hours (kVAh), corresponds to the apparent power S (kVA) and can be broken down as follows:



- Active energy (E_a): expressed in kilowatt hours (kWh). This can be used, after being transformed by the receiver, in the form of work or heat. The active power P (kW) corresponds to this energy.
- Reactive energy (E_r): expressed in kilovar hours (kVAh). This is used in particular in the windings of motors and transformers to create the magnetic field without which they would not be able to operate. The reactive power Q (kVAR) corresponds to this energy. Unlike active energy, reactive energy is said to be "unproductive" for the user.

Energies

$$E_{app} = \vec{E}_a + \vec{E}_r$$

$$E_{app} = \sqrt{(E_a)^2 + (E_r)^2}$$

Powers

$$\vec{S} = \vec{P} + \vec{Q}$$

$$S = \sqrt{(P)^2 + (Q)^2}$$

- Three-phase supply:

$$S = \sqrt{3} UI$$

$$P = \sqrt{3} UI \cos \varphi$$

$$Q = \sqrt{3} UI \sin \varphi$$

For a single phase supply the term $\sqrt{3}$ disappears.

POWER FACTOR

By definition, the power factor, or the $\text{Cos } \varphi$, of an electrical device is equal to the active power P (kW) over the apparent power S (kVA), and can vary from 0 to 1.

$$\text{Cos } \varphi = \frac{P \text{ (kW)}}{S \text{ (kVA)}}$$

It thus enables the reactive energy consumption level of devices to be easily identified.

- A power factor of 1 will result in no reactive energy consumption (resistance)
- A power factor of less than 1 will lead to reactive energy consumption which increases the closer it is to 0 (inductance)

In an electrical installation, the power factor could vary from one workshop to another depending on the equipment installed and the way it is used (off-load, full load operation, etc.).

Energy metering devices record active and reactive energy consumption. Electricity suppliers generally show the term $\text{tg } \varphi$ on their bills.

Calculation of the $\text{tg } \varphi$

$$\text{tg } \varphi = \frac{E_r \text{ (kVArh)}}{E_a \text{ (kWh)}}$$

The $\text{tg } \varphi$ is the ratio between the reactive energy E_r (kVArh) and the active energy E_a (kWh) consumed during the same period.

Unlike the $\text{cos } \varphi$, it is easy to see that the $\text{tg } \varphi$ must be as small as possible in order to have the minimum reactive energy consumption.

$\text{Cos } \varphi$ and $\text{tg } \varphi$ are linked by the following equation:

$$\text{Cos } \varphi = \frac{1}{\sqrt{1 + (\text{tg } \varphi)^2}}$$

But it is simpler to refer to a conversion table as on page 12.

Power factor (continued)

POWER FACTOR OF THE MAIN RECEIVERS

The following receivers consume the most reactive energy:

- Motors at low load
- Welding machines
- Arc and induction furnaces
- Power rectifiers

RECEIVER	COS φ	TG φ	
Ordinary asynchronous motors loaded at	0%	0.17	5.80
	25%	0.55	1.52
	50%	0.73	0.94
	75%	0.80	0.75
	100%	0.85	0.62
Incandescent lamps	approx. 1	approx. 0	
Fluorescent lamps	approx. 0.5	approx. 1.73	
Discharge lamps	0.4 to 0.6	approx. 2.29 to 1.33	
Resistance furnaces	approx. 1	approx. 0	
Compensated induction furnaces	approx. 0.85	approx. 0.62	
Dielectric heating furnaces	approx. 0.85	approx. 0.62	
Resistance welding machines	0.8 to 0.9	0.75 to 0.48	
Single phase static arc welding stations	approx. 0.5	approx. 1.73	
Arc welding transformers-rectifiers	0.7 to 0.9	1.02 to 0.48	
	0.7 to 0.8	1.02 to 0.75	
Arc furnaces	0.8	0.75	
Thyristor power rectifiers	0.4 to 0.8	2.25 to 0.75	

ADVANTAGES OF A GOOD POWER FACTOR

A good power factor is:

- A high $\cos \varphi$ (close to 1)
- Or a low $\text{tg } \varphi$ (close to 0)

A good power factor makes it possible to optimise an electrical installation and provides the following advantages:

- No billing of reactive energy
- Reduction of the subscribed demand in kVA
- Limitation of active energy losses in the cables given the decrease in the current carried in the installation
- Improvement of the voltage level at the end of the line
- Additional power available at the power transformers if the compensation is performed at the secondary