Energy University™

by Schneider Electric

Let's look at the power triangle in more depth.

Slide 11

The power triangle shown here is the simplest way to understand the effects of reactive power. The figure illustrates the relationship of active (real) and reactive (imaginary or magnetizing) power. The active power (represented by the horizontal leg) is the actual power, or watts that produce real work. This component is the energy transfer component, which represents fuel burned at the power plant. The reactive power or magnetizing power, (represented by the vertical leg of the triangle) is the power required to produce the magnetic fields to enable the real work to be done. Magnetizing power is inherently present in transformers and motors. Reactive power is normally supplied by generators, capacitors and synchronous motors.

The longest leg of the triangle, labeled apparent power, represents the vector sum of the reactive power and the real power components. Mathematically, this is equal to: $kVA = \sqrt{(kW^2 + kVAR^2)}$.

As the apparent power is the basis for electrical equipment rating, there is a big benefit to reduce the reactive power, for a given amount of active power transferred to the loads. That's why utilities are generally applying penalties on reactive power, in order to influence customers to lower the reactive power consumption.

Here we see the typical value of Power Factor for different kinds of electrical equipment.

Motor (0.8)

Incandescent lamp (1)

Compact fluorescent lamp (0.5)

Discharge lamp (0.6)

Resistance oven (1)

Computer (0.65)

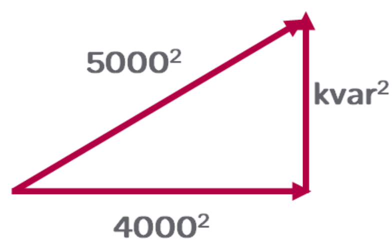
Let's move on now and do a couple of example exercises.

Slide 12

A facility is operating with a demand of 4000 kW. The 5000 kVA transformer is fully loaded. How many kvar are required to bring the power factor back to unity? Looking at the information we have been given it makes the most sense to use the power triangle formula:

$kvar^2 = kVA^2 – kW^2$

$$kvar^2 = kVA^2 - kW^2$$



$$kvar^2 = 5000^2 - 4000^2$$
$$kvar^2 = 25{,}000{,}000 - 16{,}000{,}000$$
$$kvar^2 = 9{,}000{,}000$$
$$kvar = \sqrt{9{,}000{,}000}$$
$$= 3{,}000\ kvar$$

And here we see our solution:
$kvar^2 = (5000)^2 – (4000)^2$
$kvar^2 = 25,000,000 – 16,000,000$
$kvar^2 = 9,000,000$
kvar = √9,000,000
kvar = 3,000 kvar
Let's look at another example.

Slide 13
Consider a 200 HP electric motor that has the following information on the name plate:
460 volts
228 amps
Three phase
93% efficient
All at full load
What is the power factor of this motor?

Remember the power factor ratio:
PF = kW / kVA = active power / apparent power

First calculate the kW rating of the motor from the horsepower using the formula. Remember that the horsepower given on the nameplate is the output power on the shaft. Therefore you must not only convert from horsepower to kW but must also calculate the input power from the output power.

In countries using metric units, the nameplate would normally give the output power in kW and you would be able to skip the horsepower conversion step.

1 HP = 0.746 kW
Efficiency = Output power / Input power

And so…
Input power in kW = HP x 0.746 kW x Load factor / Efficiency

The data given told us that the motor is at full load, so that is 100% or 1.
The efficiency is 93% or 0.93.
kW = 200 HP x 0.746 kW x 1 /0.93
If we do that calculation, we'll see that we come out to 160.4 kW.

Now, calculate the kVA.
In a three phase system, kVA = √3 x U x I (and remember - U is the phase to phase voltage)
kVA = 1.73 x 460/1000 x 228
kVA = 181.7

Take that one step further…
PF = 160.4/181.7 = 0.88h