

## Phase and Sign Conventions for Energy Meters

### Introduction

The relationship between voltage and current in a system being metered can be expressed in several ways, e.g. by a power factor, a phase angle, or by describing the load as inductive or capacitive. This is straight-forward when the system being metered is a net consumer of power and the phase angle is between  $+90^\circ$  and  $-90^\circ$ . It is less clear when the system is generating power and the phase angle exceeds  $90^\circ$ . This article describes appropriate conventions for four quadrant metering, covering phase angles from  $-180^\circ$  to  $+180^\circ$ .

Figures 1 and 2 indicate the phase angle/power factor convention used in all reports issued by the Measurement Standards Laboratory of New Zealand.

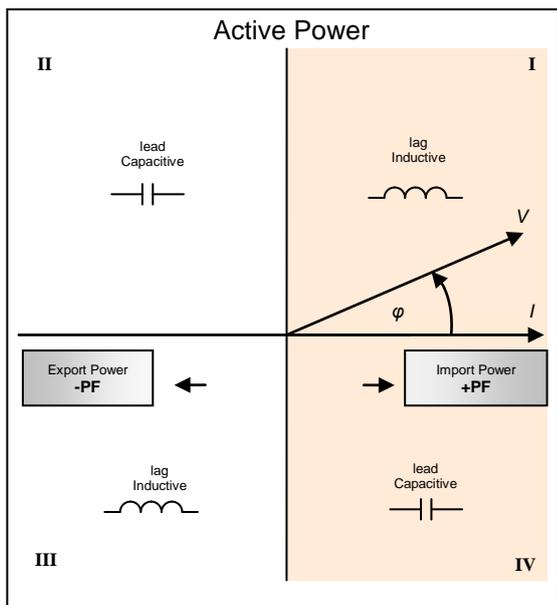


Figure 1. The sign and labeling conventions for active power.

### Conventions

The current phasor ( $I$ ) is placed in the horizontal (graphically positive  $x$ ) direction on our diagram. We lock it here for both active and reactive power, and base the rest of the diagram from this reference position. The phase angle is measured positive from the current phasor to the voltage phasor in a counter-clockwise direction. This choice of sign agrees with most European manufactured meters, but most American meters use the opposite sign (simply by using the voltage phasor as the reference). Check your meter's manual for the definition it uses.

The active power factor,  $PF$ , is positive for a meter measuring the consumption of electricity (imported power) where the phase angle is between  $-90^\circ$  and  $90^\circ$ . This is consistent with  $PF = \cos \phi$ . The load is classified as either lagging or leading depending on whether the phase shift it induces is positive or negative. The load can equivalently be classified as either inductive or capacitive.

If the meter is measuring power being generated, the phase angle will be between  $90^\circ$  to  $180^\circ$ , or  $-90^\circ$  to  $-180^\circ$  and we are in the left-hand half of our diagram. The current has reversed so the active power factor is negative (power is exported). An inductive load will place us, perhaps unexpectedly, in the lower left half of the diagram. This is a result of the load effectively being on the other side of the meter. We still describe this as lagging. Similarly the upper left quadrant is capacitive and leading.

The reactive power factor,  $QF$ , is either positive or negative depending on whether the phase angle is positive or negative. This is consistent with  $QF = \sin \phi$  and is shown in Figure 2. The positive or negative phase angle is commonly referred to as either importing or exporting reactive power, however there is no net power transfer. This choice of terminology is by analogy with active power where there is a net import or export of power.

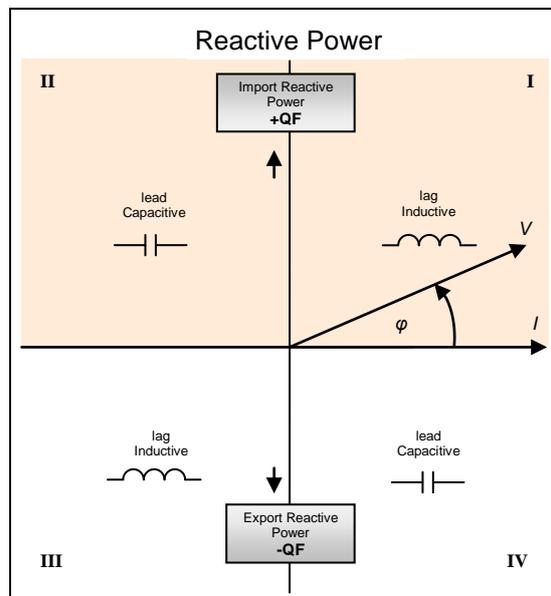


Figure 2. The sign and labeling conventions for reactive power.

## Comments

Some important points to note:

- i. Any phase angle can be described by a power factor (active or reactive), a sign, and whether it is leading or lagging.
- ii. The choice of signs is consistent with the definition of the active and reactive power factors:  $PF = \cos \varphi$  and  $QF = \sin \varphi$ .
- iii. A  $PF$  or  $QF$  of 1.0 will not have a lag/lead label but will have a sign consistent with  $PF = \cos \varphi$  or  $QF = \sin \varphi$ .
- iv. A  $PF$  or  $QF$  of zero will require an explicit sign, lag/lead label or phase angle to avoid ambiguity when used in four-quadrant metering. Typically for  $PF$ ,  $\cos(-90^\circ) = 0$  lead and  $\cos(90^\circ) = 0$  lag.
- v. The terms "imported power" or "power factor" are typically used as a default for the more explicit "imported active power" and "active power factor" respectively. Reactive power is always differentiated by adding "reactive".
- vi. By convention a positive power factor may not necessarily have an explicit "+" sign, but a negative power factor must have a "-" sign to distinguish it.
- vii. When systems are connected in series the total power factor can be found by summing the individual power factors.

## Examples

Example 1. Converting phase angle to power factor.

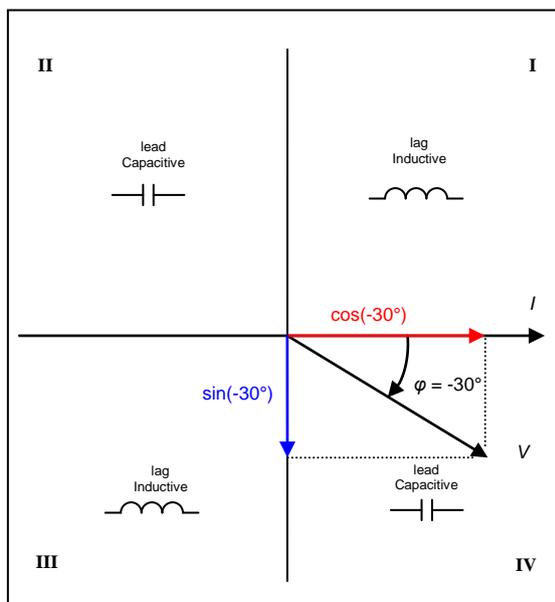


Figure 3. An example phase angle.

For the phase angle in Figure 3, the voltage phasor is in quadrant IV, so it is a "lead" label for both active and reactive power. The sign and fraction then simply come from using either  $\cos \varphi$  for active power or  $\sin \varphi$  for reactive power, ie:

$$PF = (\cos(-30^\circ)) \text{ lead} = +0.867 \text{ lead}$$

$$QF = (\sin(-30^\circ)) \text{ lead} = -0.5 \text{ lead}$$

### Example 2. Converting power factor to phase angle.

Let's say we have a  $PF = -0.8$  lead. To determine the phase angle we recognise that the  $PF$  is negative and leading, so corresponds to quadrant II. Quadrant II also corresponds to a phase angle between  $90^\circ$  and  $180^\circ$ . Therefore the phase angle can be written:

$$-0.8 = \cos(\varphi) \quad \text{where } 90^\circ < \varphi < 180^\circ$$

Which results in a solution at  $143.13^\circ$ .

If instead it is  $QF = -0.8$  lead, the negative and leading reactive power corresponds to quadrant IV. We therefore have:

$$-0.8 = \sin(\varphi) \quad \text{where } -90^\circ < \varphi < 0^\circ$$

This results in a solution at  $-53.13^\circ$ .

## References

IEC 61268:1995 or BS EN 62053-23:2003 – Both these standards for reactive energy metering include a variation on Figure 2 in their appendices (annex E for IEC 61268 and annex C for BS EN 62053-23). Note that the standard referenced by the diagrams, IEC 60375, only has the relevant information in its first edition (1972). The edition of IEC 60375 – from 2003 – omits clauses 12 and 14 of the original.

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