

CT Phase Shift and its Affect on Power Factor

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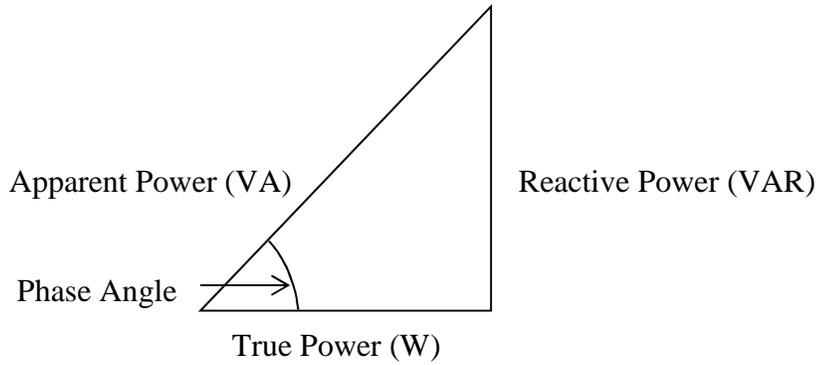
10 April 2014

When metering or monitoring the amount of power dissipated in a circuit it is important to have an accurate measurement of each of the two contributing waveforms, voltage and current. Accuracy is not only necessary for amplitude of the two waveforms, but also the phase relationship between the waveforms must be considered. Any phase angle difference between the two waveforms is known as phase shift and causes an error when trying to determine the true power consumption. When metering or monitoring, the use of components that add minimal or at least predictable amounts to the phase shift are important to allow for accurate results.

For the current measurement in metering or monitoring it is common to use a current transformer (CT) assembled around the conductor under test. However, a phase shift of the current waveform from the input of a current transformer to the output is a common problem. As with any inductive device there is a lag in time from when the signal arrives in the CT to the time the CT inductively responds and produces an output. Understanding the phase shift in the current transformer requires a look at the equivalent circuit of a transformer and an understanding of the effects of each component (See “Magnetlab Equivalent Circuit” for more on that subject). This discussion will focus on the fact that there is a phase shift and how it affects the power factor calculations.

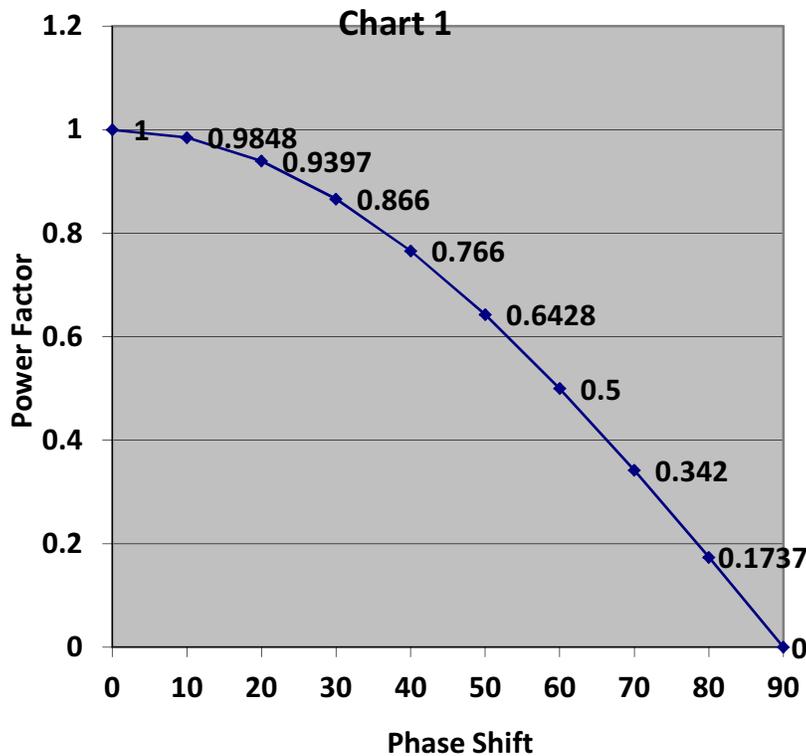
Power factor (PF) expressed as a fraction is the ratio between the true power (Watts) dissipated by the load and the apparent power (Volt Amps) that must be generated to satisfy the load. The amount of apparent power is determined by a third component, the reactive power (Volts-Amps-Reactive). The power factor is a dimensionless number between 0 and 1. When this ratio is equal to one (1) the voltage and current are in phase with each other and the true and apparent power are equal. Any shift in the current waveform from the voltage wave form creates a power factor of less than 1.

When looking at these components of power in relationship with their polar magnitudes, any PF less than 1 forms a right triangle also known as “The Power Triangle”. The true power (W) is the “X” axis (Adjacent side), the apparent power (VA) is the slope (Hypotenuse) and the reactive power (VAR) is the “Y” axis (opposite side). Because the true power and apparent power form the adjacent side and the hypotenuse side the power factor ratio is also equal to the cosine of the phase angle.

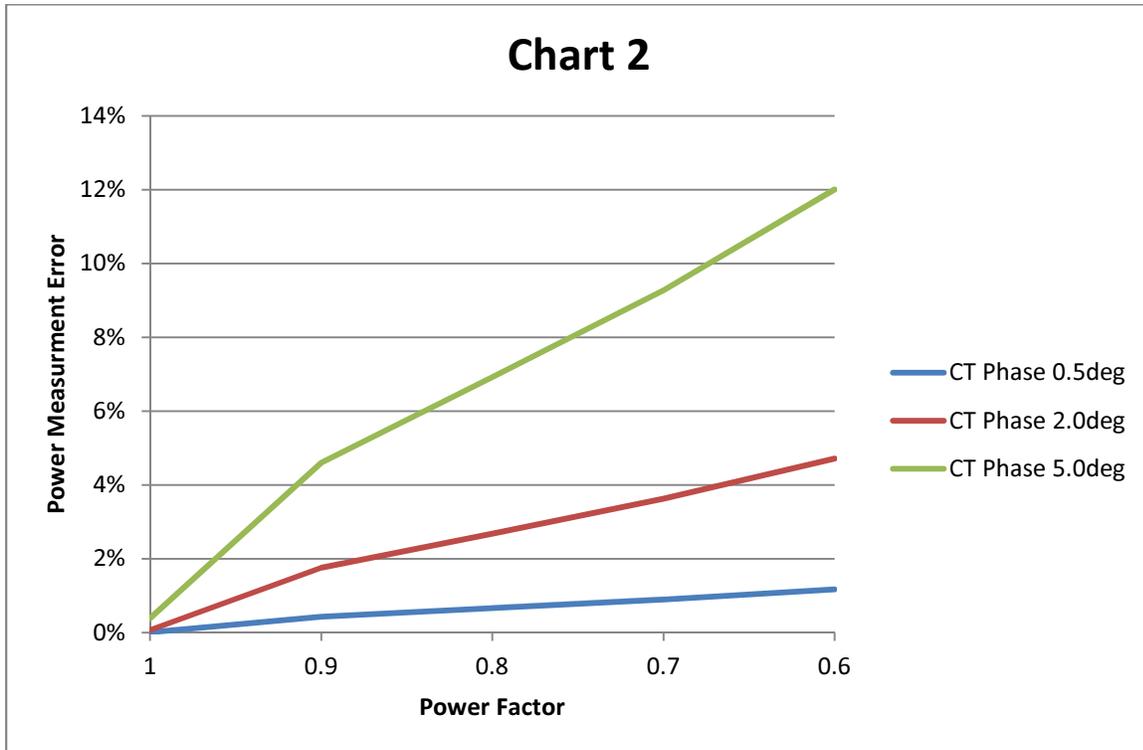


The power triangle relating apparent power to true power and reactive power

Chart 1 below shows the resulting calculated power factor as a result of the phase shift. Due to the cosine function being nonlinear, and as can be seen in the chart, a linear change in the phase shift does not result in a linear change in the PF. When measuring power using a CT for the current portion of the measurement, the phase shift of the CT results in an increases magnitude of PF error depending on the point on the curve.



When looking at the effect of the CT phase error on the power measurement it becomes obvious that the lower power factor will result in a higher measurement error as seen in Chart 2, showing the power measurement error verses the power factor with examples of CT phase angle errors.



An example of this is measuring the PF error of a circuit at a phase shift of 1 deg and another PF error of a circuit with a phase shift at 60 deg. Both examples using a CT with a 2 deg shift:

If measuring a circuit with a 1 deg phase shift using a CT with a 2 deg phase shift the resulting PF measurement is:

$$\cos 1 = 0.999848 \text{ (actual PF)}$$

$$\cos (1+2) = 0.998630 \text{ (measured PF)}$$

$$\text{Error} = 0.001218 \text{ or } 0.122\%$$

If measuring a circuit with a 60 deg phase shift using a CT with a 2 deg phase shift the resulting PF measurement is:

$$\text{Cos } 60 = 0.500000 \text{ (actual PF)}$$

$$\text{Cos } (60+2) = 0.469472 \text{ (measured PF)}$$

$$\text{Error} = 0.03053 \text{ or } 6.1\%$$

In the two examples the CT has not changed and is still accurate to 2 deg, however the PF accuracy has almost no added error when added to the 1deg phase shift, but is significantly affected by the small phase shift in the CT when added to the phase shift of 60 deg. The 6.1% error above may seem small, but consider a common household power consumption in one month may be 500KWH or more, and the PF error caused by the phase shift at 60deg:

Apparent power = True power/Power factor

$$\text{VA} = 500,000/0.500000 = 1,000,000 \text{ (actual VA)}$$

$$\text{VA} = 500,000/0.469472 = \underline{1,065,026} \text{ (measured VA)}$$

$$65,026 \text{ VA error}$$

As shown above, the error can add up and cause large discrepancies in power generation requirements and usage.

When designing or evaluating a power measuring system the affect of the CT phase shift on the power factor must be considered based on the characteristics of the circuit under test and the affect they can have on the resulting measurements.

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