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Capacitive Current and Standby Loss

PHASEPERFECT®
Digital Phase Converter

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Authors:
Nicholas Kingsbury | President
Peda Medagam | Chief Engineer
Jacey Planteen | Quality Manager

Capacitive Current and Standby Loss for the Phase Perfect® 240V Digital Phase Converter

Introduction

The Phase Perfect utilizes filter capacitors to reduce electronic switching noise that is created by the active switching technology employed in its architecture. These filter capacitors cause the system to circulate reactive power. The purpose of this white paper is to explain what capacitive current or power is, how it affects stand-by losses, and why measured stand-by current does not equate to consumed power and is not billed for by the utility.

Capacitive Power Fundamentals

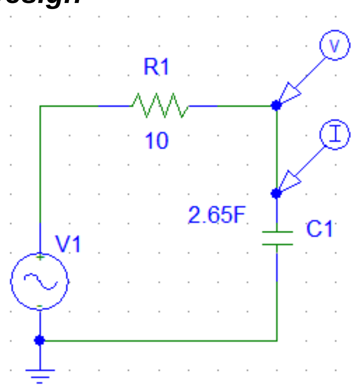
Our Phase Perfect systems utilize LC filtering (inductors and capacitors) to reduce noise from the switching technology. Capacitors and inductors do not dissipate or consume power. Capacitors store energy in the form of electrical charge, and inductors store energy in the form of a magnetic field. These components both have a net effect of zero, as they alternate between supplying and consuming energy.

In an AC circuit, capacitors and inductors continually charge and discharge at even rates. This means that the *average* power through these components is 0. Half of the period of the power waveform is spent absorbing power, and the other half of the period is spent supplying power. Averaging these two parts together yields no net power loss because the charging and discharging curves are symmetrical.

Example

Below is an example of how AC power functions in a simple circuit with a reactive load. This circuit, illustrated in Figure 1, is composed of a resistor representing line resistance (10 ohms is a very small resistance) and a capacitor.

Figure 1. Simple RC Circuit Design



Assume this circuit is supplied with a 240V 60Hz source. Figure 2 below shows one complete cycle of the voltage and current waveforms through the capacitor, as measured by probes “V” and “I” in

Figure 1 above. Note that the current waveform has been scaled up to match the range of the voltage curve. Using a large capacitance value like 2.65F gives a very clean current waveform to compare to the voltage.

Figure 2. Voltage and Current Waveforms through the Capacitor

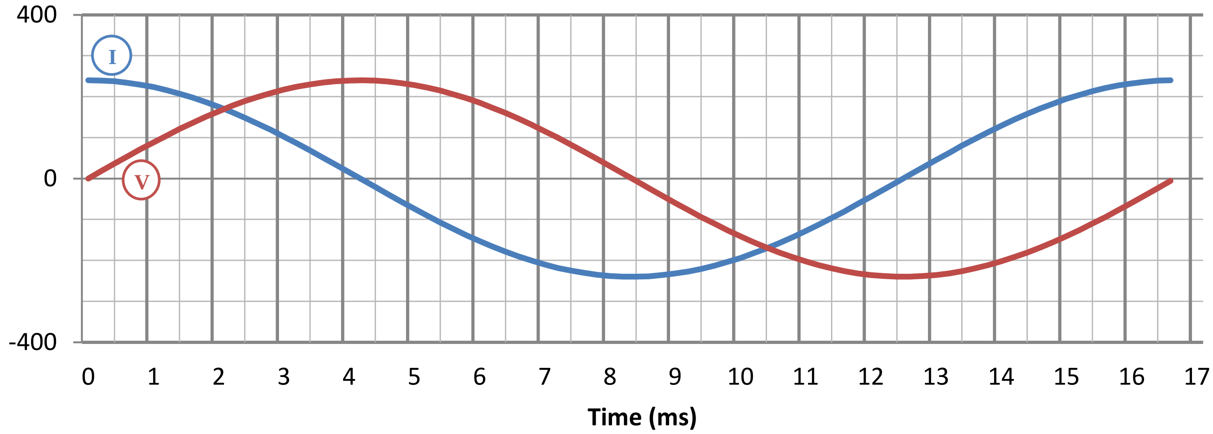
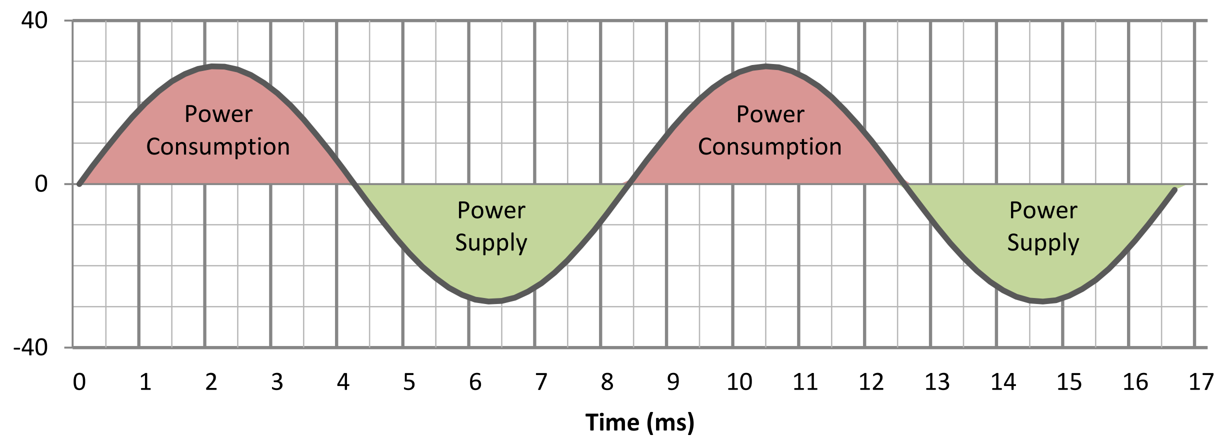


Figure 3 illustrates the instantaneous power through this simple circuit as measured at "V1" in Figure 1. The instantaneous power is the product of the current at voltage at any point in time. The cyclical nature of this waveform oscillates between power consumption and power supply as previously discussed.

Figure 3. Instantaneous Power in the Simple RC Circuit



Phase Technologies, LLC
222 Disk Drive
Rapid City, SD 57701
www.phasetechnologies.com

605-343-7934 - Main
866-290-7934 – Toll Free
605-343-7943 - Fax

The formula for average power in an ideal AC system is:

$P = V_m \cdot I_m \cdot \cos(\theta)$

where m = magnitude
P = power
V= voltage
I = current
θ = phase angle (between voltage and current curves)

In this example circuit, there is always a phase angle of 90° because a purely reactive load (a load composed entirely of capacitors and/or inductors) causes a phase shift of 90°. If θ is always 90°, then cos(θ) will always be 0. Regardless of the voltage or current, the *average* power of an AC circuit in this configuration will always be 0W. However, as Figure 3 illustrates, even though the average power is 0, the instantaneous power does vary.

Phase Perfect Stand-By Power

The Phase Perfect systems are much more complex than the simple RC circuit explored up to this point. However, the same general concepts do apply. Due to the LC filtering in the Phase Perfect systems, the filter capacitors are alternately charging and discharging.

Table 1 calculates the expected currents when measuring a system in stand-by. The formula for calculating the current in a Phase Perfect system in stand-by is:

$I = 2\pi \cdot V \cdot f \cdot C$

where f = frequency
C = capacitance

Table 1 calculates this expected circulating current in stand-by mode for the various Phase Perfect models. These currents are not consumed, but reflected back to the source.

Table 1. Expected Circulating Current in Phase Perfect Systems

Model	PT330	PT355	PT380	PT3110	PT3160
Capacitance [C] (µF)	40	80	60	160	240
Voltage [V] (V)	240	240	240	240	240
Frequency [f] (Hz)	60	60	60	60	60
Current [I] (A)	**3.62**	**7.24**	**10.85**	**14.48**	**21.71**

Unlike the ideal circuit explored in the example, the Phase Perfect has losses, which means that the system is not 100% efficient. The system is consuming a nominal amount of energy, even in stand-by mode.

Utility meters only measure power consumed (i.e. currents that are greater than 0). In a Phase Perfect system, the utility meter will not register the circulating current (which averages to no net power consumption). The utility is measuring an average of the current flowing to the capacitors and being reflected back to the source. For a PT330 system, the current measured at the PT330 is approximately 4.06A in stand-by mode. Per Table 1, the circulating current is approximately 3.62A. Approximately 0.44A (the net difference) is consumed by the Phase Perfect. Thus, the stand-by power consumption for a Phase Perfect system is:

$$P = V \cdot (I_{converter} - I_{reflected})$$

where V = utility voltage
$I_{converter}$ = current measured at the Phase Perfect system
$I_{reflected}$ = circulating current reflected back to the source

For the PT330 system, the stand-by power consumption is:

$$P = 240V \cdot (4.06A - 3.62A) = 105.6W$$

Summary

Filter capacitors in Phase Perfect systems alternate between charging and discharging, creating a reactive load which consumes no power. The actual peak currents that may be measured at the source to a Phase Perfect unit will be much higher than what is actually being consumed. The actual power consumption is the difference between this current and the current that is reflected back to the source due to circulation.

Utility meters only measure current consumption, NOT circulation. Thus, though the amount of current passing through the Phase Perfect system may be significant, the utilities are only charging for the net power consumed, NOT the reactive current.

About Phase Technologies

Founded in 1999, Phase Technologies developed Phase Perfect® Digital Phase Converters, the first major advancement of phase conversion technology in decades. Recognized as the world's leading manufacturer of phase converter technologies, the company expanded its product offerings to include variable frequency drives (VFD's).

Specializing in VFD with Active Front End technology, Phase Technologies produces the only low harmonic, fully regenerative, phase-converting VFD that complies with IEEE 519, the international standard for allowable harmonic levels on utility mains. The company has an extensive product line-up of low harmonic, fully regenerative drives in both three-phase and phase-converting models.

Phase Technologies relies on a team of in-house power electronics and mechanical design engineers to develop innovative products, encompassing all aspects of hardware and firmware design. All products are manufactured at our facilities in the USA under exacting quality standards. In-house processes include printed circuit board population and custom magnetics fabrication.

The company operates a certified UL508A panel shop to integrate our drives into rugged outdoor panels with custom options for applications including irrigation, oil and gas production and general industrial control.

Integrity and honesty are the cornerstones of customer interaction at Phase Technologies. Knowledgeable sales experts are available to help customers select the right product to fit their needs, and we partner with the best distributors and dealers to make our products available with rapid delivery times and local service. Experts in our customer service department are standing by to answer technical questions and provide the support to keep your application up and running.

For more information, visit www.phasetechnologies.com

Media Contact
Lisa Johnson
Marketing Manager
605-343-7934
marketing@phasetechnologies.com