

Power Factor

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1. Difference Between VA & Watts

The purpose of this Tech Note is to clear up a common misunderstanding about the measurement of power in alternating current (AC) circuits. Most people with electrical experience have heard that power equals amps times volts. This is always true for direct current (DC) circuits, but the situation is more complicated with AC circuits. If an AC load is purely a resistive load, such as incandescent light bulbs and heaters without fans, then the power is indeed the product of volts and amps. However, in the world of alternating currents, there are three types of "power":

- A. Apparent power, which is the product of rms (root mean square) volts and rms amps. (VA, volt-amps)
- B. Real power, which is the time average of the instantaneous product of voltage and current. (Watts)
- C. Reactive power, which is the time average of the instantaneous product of the voltage and current, with current phase shifted 90 degrees. (VAR, volt-amps reactive)

Apparent power (VA) is the easiest to measure; it is what you get when you measure the rms volts with one meter and the rms amps with another meter and multiply the two.

$$P = V \times A = VA$$

Equation 1; Apparent Power

The measurements must be made with "True RMS" meters. Unfortunately, this does not represent the real power consumed by a "reactive" load such as a motor.

A person may measure that a well pump consumes 120 V and 6 A. It would seem that this means it uses a total of:

$$P = 120 \text{ V} \times 6 \text{ A} = 720 \text{ Watts}$$

Equation 2; Incorrect Calculation of Real Power

However, this is only a calculation of apparent power, which is really measured in VA and is not equal to the real power consumed. The well pump has a power factor (PF) associated with it. PF is the ratio of real power to apparent power.

$$PF = \text{Real Power} / \text{Apparent Power}$$

Equation 3; Power Factor

When the pump operates, it has some magnetic characteristics resulting in drawing a larger "apparent" power (VA) than "real" power (Watts). Measurement of the real power (definition B above) requires the use of special instruments. There is an older style of meter called an electrodynamic wattmeter which can measure real power; a modern equivalent would be the Fluke model 41 power meter. The Fluke meter can only achieve an accuracy of a few percent because of its use of a clamp-on current probe. Accuracy of less than 1 percent will require avoiding the clamp-on probe for measuring the current. The Fluke 41 also measures the "power factor" (PF), which is the real power divided by the apparent power. If the well pump's PF is 0.8 this could be used to calculate the real power by:

$$P = 120 \text{ V} \times 6 \text{ A} \times 0.8 = 576 \text{ Watts}$$

Equation 4; Correct Calculation of Real Power

Therefore, it is correct to calculate AC Watts by:

$$P = V \times A \times PF = \text{Watts}$$

Equation 5; Real Power

The PF is used to compute real power. Real power is always expressed in Watts, while apparent power is expressed in VA.

The reason real power is important is that the power consumed by an inverter from a battery is proportional to the real power delivered to the load, not the apparent power. Two separate meters (measuring amps and volts) cannot measure the real power unless the load is purely resistive (for example, incandescent light bulbs or heaters without fan motors).

2. Definition of a VAR (Volt-Amp-Reactive)

Magnetic loads, such as motors, can draw more VA power than actual real power. The extra component is called a VAR. A VAR is basically magnetic power, which causes a phase shift between voltage and current curves.

This phase shift between voltage and current reduces the overlap between the two curves and effectively delivers less power to the loads - See Figure 1.

Power Factor

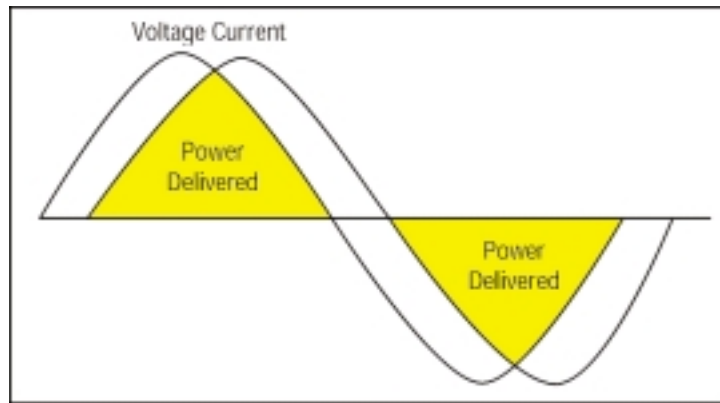


Figure 1. Voltage to Current Phase Shift

3. Graphical Representation of Real Power, Reactive Power, Apparent Power and Power Factor

Real power, VA and VAR's are related as vectors, shown in the diagram below. The apparent power is the square root of the sum of the squares of the reactive power and the real power.

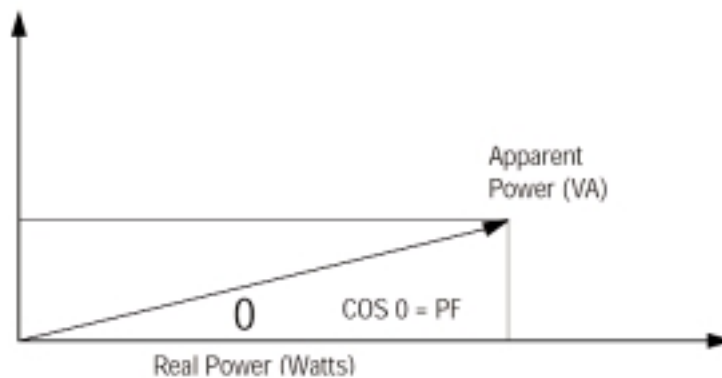


Figure 2, Relationship Between the Three Types of Power

The vector graph above illustrates the components of a power draw. The VAR component represents the reactive power component while the watt component represents real power. The combination of the two represents VA, the apparent power. The angle between the real power axis (horizontal) and the apparent power vector is theta. The cosine of angle theta is equal to the power factor, as identified in equation 3. Often, electrical equipment manufacturers will identify the power factor by cos (theta), rather than PF.

Thus, when an inverter is operating loads with power factors less than 1, the inverter capacity is effectively reduced. If a 5000 VA inverter has a 5000 VA, 0.8 PF load connected, the real power output of the inverter is only 4000 watts. In this scenario, the capacity of the inverter is fully utilized, and the batteries will be drained as though we had a load of 4000 watts, the real power, and not 5000 watts, the VA on the battery bank.

The efficiency in the previous example will be approximately that found on the inverter efficiency curve at the 5000 VA level, which is lower than the 4000 VA efficiency, even though the inverter is only providing 4000 real watts. This lower efficiency is the penalty associated with low power factor loads.

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