



Technical Note 14:

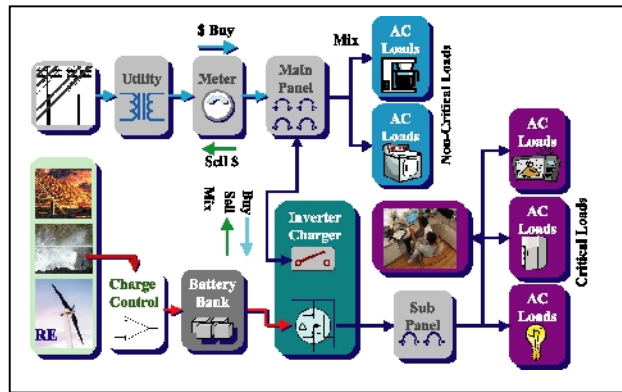
Displaced Power Factor Correction

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Overview

An inverter charger can be used as backup power supply, utilizing batteries; it can sell excess power to the utility; or it can be used to supplement power consumed by critical loads. Since the inverter supplies power to the load and utility at one common point, if excessive amounts of displaced power factor are present (on the line side), reactive loads may reduce the real power sold to the utility. This could also increase harmonics caused by the reactive loads.



Typical Inverter Charger Block Diagram

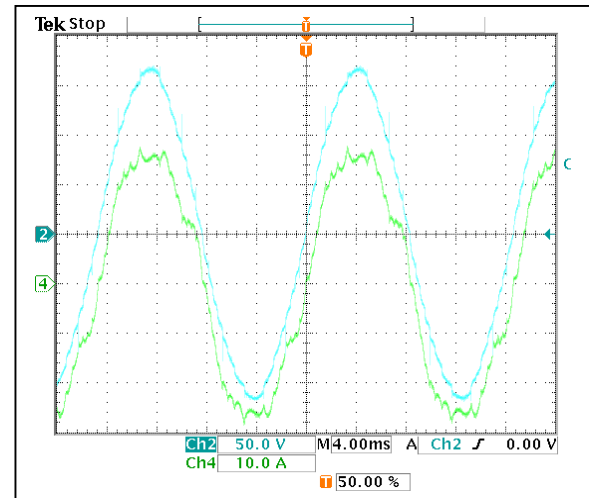
The end result is the utility NET power meter may read a lower return rate than expected. Typically, when power factor correction is required, the utility power company will add PFC caps at the utility's high voltage side (for large displaced loads > 10Kvars). Locally, the end user can add smaller AC filter caps at the inverter charger (typically < 2Kvars) to reduce inductive reactance.

Displaced Power Factor Effects

Displaced power factor is a dynamic condition that changes in respect to load or conditions on the grid such as.

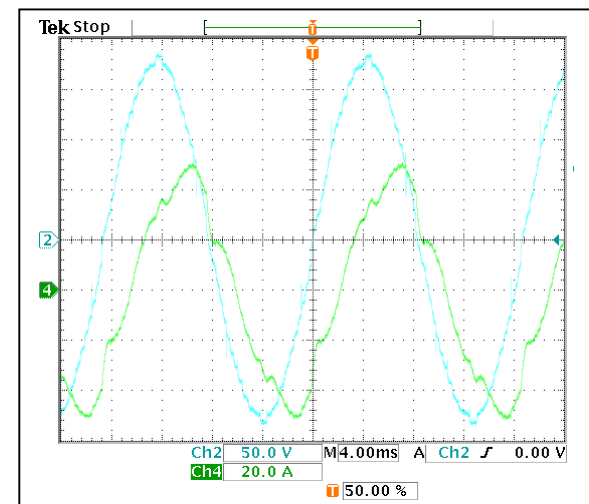
- Grid displaced power factor (caused by lack of power factor correction)
- Local grid power factor correction devices switched into or off the grid (changes the grid reactance)
- Residential inductive or capacitive reactive loads

The examples below are pictures of phase angles between current and voltage.



Current & Voltage In Phase - Power Factor near 0.95

Displaced power factor with current lagging voltage is typically referred to as inductive reactive displaced power factor. The external resistive loads are still consuming the same amount of power, but the resultant phase shift causes the inverter to circulate reactive current within the inverter



itself.

Current & Voltage Out of Phase - Power Factor 0.71 Lag

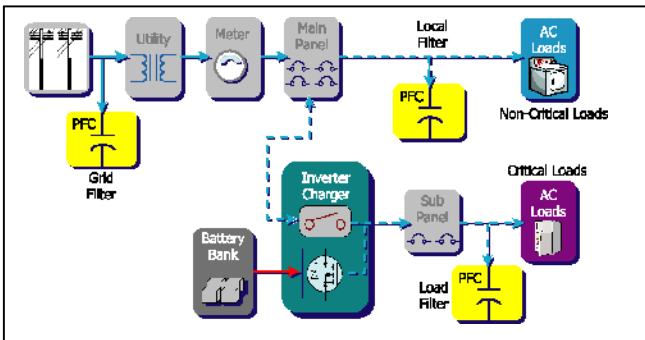
Power Factor Correction Devices

Displaced power factor in residential communities is mainly inductive reactive caused by refrigerators, air conditioners, furnaces, septic pumps, and even the "pole pig" (power pole or underground mounted high voltage to low voltage 240 V transformer).

To correct power factor, the utility company adds Power Factor Correction (PFC) capacitors on the utility side of the residential transformer. [Ref 1]

In most cases, the PFC does not correct local inductive reactive loads within the residence. These loads can be corrected using local filters as shown below.

When using backup inverter chargers, some loads have displaced power factor that induce circulating currents within the inverter which can be corrected using a load filter, as shown below, after the critical load sub panel.



Examples of PFC Installed Devices

Motor run capacitors can be utilized as AC filters or to provide small capacitive reactive displacement because they are designed for continuous connection to the line (with proper current limiting protection). It is assumed that adding AC filter capacitors is only needed when power factor issues



create a problem.

50uF 370VAC Motor Run Cap

AC motor run filter capacitors are typically hard wired to the circuit breaker side of the main panel, or at the sub panel, to displace inductive reactance power factor. In either case, overcurrent protection must be utilized as described later in this technical note.

Calculating for Power Factor Correction:

There are situations where overcorrecting displaced power can cause issues when combined with AC motors when the back EMF from the motor (after power is turned off) resonates with the PFC capacitors. It is recommended to correct to a 0.95pf (less capacitance) to mitigate overcorrecting issues.

There are a several methods to determine the amount of displaced power factor correction required (one method is shown below as an example). Another example discusses power factor stated in a Xantrex Technology Inc., Tech Note [Ref 2].

To determine the amount of power factor correction requires a few steps to solve for the capacitance. The basic formulas used are shown below:

Apparent Power	$VA = \text{Volts} \times \text{Amps (EI)}$
Active Power	$\text{Watts} = Pf \times VA$
Reactive Power	$\text{Var} = \sqrt{VA^2 - \text{Watt}^2}$

To measure displaced power factor, special equipment is required utilizing power quality metering equipment from companies such as BMI, Fluke, Dranetz, etc. The examples below assume using a Fluke 41 or the Fluke 43.

As an example, calculate the reactive Vars (Volt Amp Reactive) within the circuit with 1000 VA load at a power factor of 0.85 lagging (inductive), 120 VAC, and 60 Hz line frequency? Once this value is determined, then solving for capacitance is straightforward.

In the following formulas, solve for apparent power.

$$W = 1000 VA * 0.85 Pf = 850 \text{ watts}$$

Then, solve for reactive power:

$$\text{Vars} = \sqrt{1000 VA^2 - 850 W^2} = 526.8 \text{ Vars}$$

Where Vars are Volt Amp Reactive and watts are the real power consumed in the circuit

To correct the 525 inductive power factor (Vars), the amount of capacitance depends upon on the ratio of voltage across the circuit and effective current through the reactive circuit. The following example is used to show the process to solve for the value of capacitor needed.

First, solve for circuit impedance using this formula:

$$Z = \frac{E^2}{\text{Vars}}$$

Where Z is the circuit impedance in ohms, E^2 is the potential voltage across the circuit, and the Vars are the inductive Vars.

$$Z = \frac{120 \text{ VAC}^2}{525 \text{ Vars}} = 27 \text{ ohms}$$

If the impedance $Z = 27$ ohms, then 27 ohms of capacitance reactance (X_c) will cancel the inductive reactance in the circuit. To solve for the required capacitance reactance, transpose the following formula:

$$C = \frac{1}{(377 \cdot X_c)}$$

Where X_c is the capacitive reactance in ohms, f in hertz, and C is in farads.

Solving the formula above [$2(f) = 377$ at 60 Hz, then solve for capacitance:

$$X_c = \frac{1}{2\pi f C}$$

Where C is the Capacitance in micro farads (μF), and X_c is the reactance in ohms, and 377 is the product of $2 \times \pi \times [f]$.

Thus, the amount of capacitance required is:

$$C = \frac{1}{(377 \cdot 27 \text{ ohms})} = 98 \mu\text{F}$$

A motor run capacitor of 75 to 90 μF would be needed to correct the 525 Vars of the inductive reactive displaced power factor to 0.90 to 0.95 pf.

Capacitor Overcurrent Protection

The fusing that is required for each capacitor is 135% of the rated capacitor current:

$$I = \frac{E}{R} \text{ is } \frac{120 \text{ VAC}}{27 \text{ ohms}} = 4.4 \text{ amps}$$

** Thus **

$$4.4 \text{ amps} \cdot 135\% = 6 \text{ amp SB fuse}$$

Where E is the potential voltage across the capacitor, and R is the capacitive reactance in ohms, I is the current through the capacitor.

Some AC motor run capacitors utilize internal protection devices and may only be rated for 15 amp circuits. Typical inverter circuits, for example the Sine Wave Series, may be rated as high as 60 amps. Each added capacitor should be series fused to provide overcurrent protection should the capacitor internally fail.

Bussmann (type SB or GC, 15 amp 250 VAC, series fuse (and holder) for each 50 - 100 μF capacitor should provide the overcurrent protection required. For larger capacitor banks, a fuse link for capacitor protection should be capable of continuously carrying 135% of the rated capacitor current, and must withstand, without damage, the normal transient current during bank energization or de-energization. [Ref 1, pp 10-114, par 266 and 268].

Conclusion

Inverter chargers may not be affected by displaced power factor, but will not run as efficiently as expected. Proper PFC or motor run capacitors should be utilized as described above and installed per the National Electric Code NEC [Ref 3].

References

- [1] Fink, Donald., Beaty H., 1987, Standard Handbook for Electrical Engineers, 12th Edition, McGraw-Hill Book Company, New York, NY.
- [2] Trace Engineering, 4/2/1999, Technical Note #11, Power Factor. Xantrex Technology Inc., Arlington WA.
http://www.traceengineering.com/technical/tech_notes/index.html
- [3] NEC, Std NEC 2002, National Electrical Code, NFPA 70, National Fire Protection Association Inc., Quincy