

Model PFC
Power Factor Correction Capacitors

Customer Reference Manual

Bonitron, Inc.
Nashville, TN



An industry leader in providing solutions for AC drives.

ABOUT BONITRON

Bonitron designs and manufactures quality industrial electronics that improve the reliability of processes and variable frequency drives worldwide. With products in numerous industries, and an educated and experienced team of engineers, Bonitron has seen thousands of products engineered since 1962 and welcomes custom applications.

With engineering, production, and testing all in the same facility, Bonitron is able to ensure its products are of the utmost quality and ready to be applied to your application.

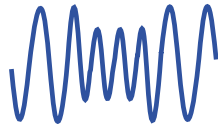
The Bonitron engineering team has the background and expertise necessary to design, develop, and manufacture the quality industrial electronic systems demanded in today's market. A strong academic background supported by continuing education is complemented by many years of hands-on field experience. A clear advantage Bonitron has over many competitors is combined on-site engineering labs and manufacturing facilities, which allows the engineering team to have immediate access to testing and manufacturing. This not only saves time during prototype development, but also is essential to providing only the highest quality products.

The sales and marketing teams work closely with engineering to provide up-to-date information and provide remarkable customer support to make sure you receive the best solution for your application. Thanks to this combination of quality products and superior customer support, Bonitron has products installed in critical applications worldwide.

AC DRIVE OPTIONS

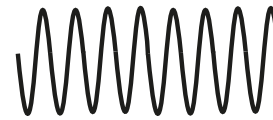
In 1975, Bonitron began working with AC inverter drive specialists at synthetic fiber plants to develop speed control systems that could be interfaced with their plant process computers. Ever since, Bonitron has developed AC drive options that solve application issues associated with modern AC variable frequency drives and aid in reducing drive faults. Below is a sampling of Bonitron's current product offering.

WORLD CLASS PRODUCTS



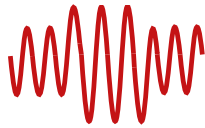
Undervoltage Solutions

Uninterruptible Power for Drives
(DC Bus Ride-Thru)
Voltage Regulators
Chargers and Dischargers
Energy Storage



Power Quality Solutions

12 and 18 Pulse Kits
Filtering
Noise and Transient Suppression
Power Factor Correction



Overvoltage Solutions

Braking Transistors
Braking Resistors
Transistor/Resistor Combo
Line Regeneration
Dynamic Braking for Servo Drives



Common Bus Solutions

Single Phase Power Supplies
3-Phase Power Supplies
Common Bus Sharing Diodes
Isolation Diodes
Bus Filter Capacitance



Green/Sustainable Solutions

Voltage Boosters
(for Solar and Wind Applications)
Line Regeneration
Power Factor Correction



Portable Maintenance Solutions

Capacitor Formers
Battery Testers
Capacitor Testers
Capacitor Dischargers

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1. INTRODUCTION

1.1. WHO SHOULD USE

This manual is intended for use by anyone who is responsible for integrating, installing, maintaining, troubleshooting, or using this equipment with any electrical system.

Please keep this manual for future reference.

1.2. PURPOSE AND SCOPE

This manual is a user's guide for the Model PFC. It will provide the user with the necessary information to successfully install and operate the equipment.

In the event of any conflict between this document and any publication and/or documentation related to local codes or regulations, the latter shall have precedence.

1.3. MANUAL VERSION AND CHANGE RECORD

Rev 01a of this manual clarifies information.

Figure 1-1: PFC



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2. PRODUCT DESCRIPTION / FEATURES

With today's energy prices and pricing structures, electricity bills are rising. You can reduce your energy costs by optimizing your electrical load to minimize kVA, demand and power factor charges. Motors and other inductive loads in your facility can cause poor power factor, and increase the apparent power used. Most electrical companies bill based on kVA and may have extra power factor charges.

Power factor correction is used to offset the lagging power factor caused by motors and inductive loads in power systems. Reducing this power factor will result in lower utility demand, lower demand bills, lower power factor penalty charges, and lower losses in the power system due to I^2R losses.

This application of capacitors is long established and well known to reduce the amount of total power required by inductive loads.

Inductive loads require magnetizing VARs (reactive power) to operate, and operate at a lagging power factor. Capacitors provide these magnetizing VARs, reducing the current draw in the system, and thereby reducing the total VA (power) required from the power system. By reducing this reactive power, the demand from the utility is lowered, thereby lowering demand charges, and saving money on billing.

Bonitron's PFC units are designed to be distributed in the internal power grid of a site to allow for flexible sizing to the load and VAR requirement. This also can have the added benefit of reducing the current in the internal grid, allowing for smaller transformers and lower line losses that can add 1 – 2% power in lines that carry this reactive current. These losses are seen in bus heating that may also have an effect on the cooling requirements of a facility.

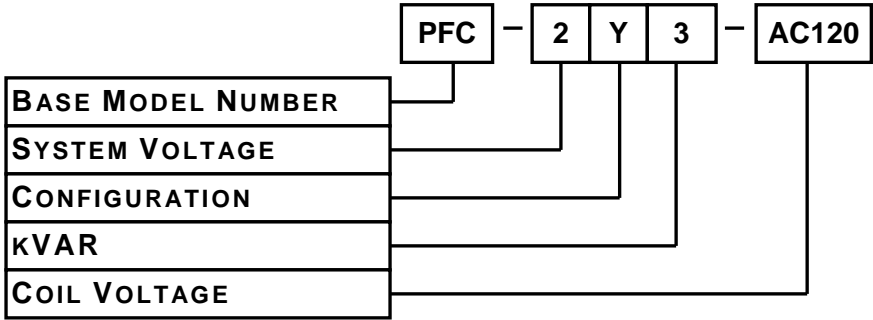
Bonitron's PFC units also incorporate high frequency filter capacitors and Metal Oxide Varistors to allow for some reduction in electrical noise that can cause damage to sensitive equipment.

The Bonitron PFCs can be installed individually, or in parallel groups for larger kVAR loads.

Bonitron's Power Factor Correction modules incorporate capacitors that are designed to disconnect from the power source in the event of overheating to allow for increased safety from capacitor failure. Integral discharge resistors allow for self discharge at shutdown to allow for safe handling when power is removed.

2.1. PART NUMBER BREAKDOWN

Figure 2-1: Example of Part Number Breakdown



BASE MODEL NUMBER

The Base Model Number for all Bonitron Power Factor Correction Capacitors is **PFC**.

SYSTEM VOLTAGE RATING

The System Voltage Rating indicates the voltage level of the electrical system. This level is indicated by a numerical code as shown in Table 2-1.

Table 2-1: System Voltage Rating Codes

RATING CODE	VOLTAGES (NOMINAL AC LINE)
2	208/240 VAC
4	460/480 VAC

CONFIGURATION

The Configuration indicates the internal connection of the power factor correction capacitors. The Configuration is indicated by a single letter code.

Table 2-2: Configuration Codes

CODE	CONFIGURATION
D	Delta (3W + G)
Y	Wye (4W + G)
H	Hybrid (4W+G)

KVAR

This indicates the amount of kVAR at rated voltage.

COIL VOLTAGE

This indicates the coil voltage of the internal contactor for remote operation.

Table 2-3: Coil Voltages

CODE	CONFIGURATION
DC 24	24 V DC
AC 120	120 VAC
AC 240	240 VAC
AC 480	480 VAC

2.2. GENERAL SPECIFICATIONS

Table 2-4: General Specifications Table

PARAMETER	SPECIFICATION
Voltage Ranges	208-480VAC
Reactance	3-60kVAR
Indicators	Front panel LEDs for PFC status
Operating Temp	0° to + 35°C (32°F to +95°F)
Storage Temp	0° to + 40°C (32°F to +104°F)
Humidity	Below 90% non-condensing
Atmosphere	Free of corrosive gas and conductive dust

2.3. GENERAL PRECAUTIONS AND SAFETY WARNINGS



DANGER!

- **HIGH VOLTAGES MAY BE PRESENT!**
- **NEVER ATTEMPT TO OPERATE THIS PRODUCT WITH THE ENCLOSURE COVER REMOVED!**
- **NEVER ATTEMPT TO SERVICE THIS PRODUCT WITHOUT FIRST DISCONNECTING POWER TO AND FROM THE UNIT.**
- **ALWAYS ALLOW ADEQUATE TIME FOR RESIDUAL VOLTAGES TO DRAIN BEFORE REMOVING THE ENCLOSURE COVER.**
- **FAILURE TO HEED THESE WARNINGS MAY RESULT IN SERIOUS BODILY INJURY OR DEATH!**



CAUTION!

- **THIS PRODUCT CAN GENERATE HIGH TEMPERATURES DURING OPERATION.**
- **THIS PRODUCT SHOULD BE INSTALLED ACCORDINGLY ON NON-FLAMMABLE SURFACES WITH CLEARANCES OF AT LEAST TWO INCHES IN ALL DIRECTIONS.**
- **NO USER-SERVICEABLE PARTS ARE CONTAINED WITHIN THIS PRODUCT. INOPERABLE UNITS SHOULD BE REPLACED OR RETURNED FOR EVALUATION AND/OR REPAIR BY QUALIFIED TECHNICIANS.**
- **BEFORE ATTEMPTING INSTALLATION OR REMOVAL OF THIS PRODUCT, BE SURE TO REVIEW DOCUMENTATION FOR PERTINENT SAFETY PRECAUTIONS.**
- **INSTALLATION AND/OR REMOVAL OF THIS PRODUCT SHOULD ONLY BE ACCOMPLISHED BY A QUALIFIED ELECTRICIAN IN ACCORDANCE WITH NATIONAL ELECTRICAL CODE OR EQUIVALENT REGULATIONS.**

ANY QUESTIONS AS TO APPLICATION, INSTALLATION, OR SERVICE SAFETY SHOULD BE DIRECTED TO THE EQUIPMENT SUPPLIER.

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3. INSTALLATION INSTRUCTIONS



Installation and/or removal of this product should only be performed by a qualified electrician in accordance with National Electrical Code or local codes and regulations.

Proper installation of the PFC Power Factor Correction should be accomplished following the steps outlined below. Please direct all installation inquiries that may arise during the installation and start up of this product to the equipment supplier or installer.

3.1. ENVIRONMENT

The module should be installed in an area protected from moisture and falling debris. Buildup of dust or debris may cause poor performance and possibly failure. Operating in a wet environment can pose a shock hazard.

3.2. UNPACKING

Upon receipt of this product, please verify that the product received matches the product that was ordered and that there is no obvious physical damage to the unit. If the wrong product was received or the product is damaged in any way, please contact the supplier from which the product was purchased.

3.3. MOUNTING

3.3.1. MOUNTING THE PFC POWER FACTOR CORRECTION CAPACITORS

The installation site for the module should be chosen with several considerations in mind:

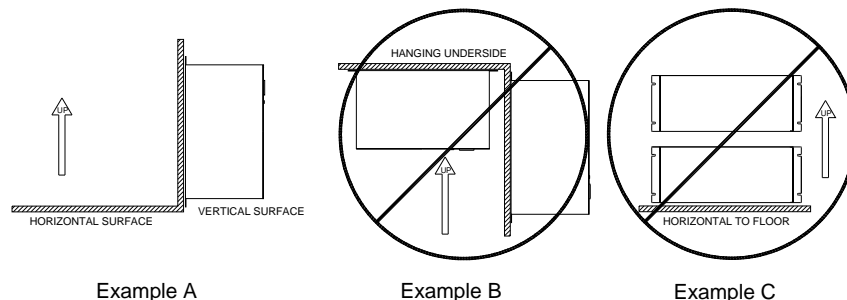
The unit requires a minimum clearance of two (2) inches in all directions around it when mounted near a non-heat source.

Unit should not be exposed to falling debris or condensation.

Once the installation site has been selected as outlined above, the unit should be mounted in place. The PFC must be properly oriented for proper heat flow through the units. The PFC must be mounted with the rear surface of the unit to the mounting surface. **Unit should be mounted vertically** as shown in Example A of Figure 3-1.

- **Do NOT** mount the unit upside-down or on the underside of a mounting surface as shown in Example B of Figure 3-1.
- **Do NOT** mount unit in a horizontal position with its side parallel to the mounting surface or floor as shown in Example C of Figure 3-1.

Figure 3-1: PFC Mounting Orientation



3.4. WIRING AND CUSTOMER CONNECTIONS

3.4.1. POWER WIRING



WARNING!

- *Power factor correction capacitors can cause harmonic resonance under certain conditions. See application notes for further information on harmonics and resonance.*
- *Do NOT install on systems that have DC motor drives, specifically phase controlled DC motor drives, without consideration. See the Application Notes in Section 7 for further information on harmonics.*
- *DO NOT place the power factor correction capacitors directly to the output of a soft start controller. Severe damage to the capacitors or soft start controller will result.*

The power terminals should use suitable wiring for the installation. In general, this will be UL listed wire for use in conduit, such as TFFN.

Each PFC module should have an individual, dedicated overload and/or overcurrent device, such as a circuit breaker or fuses to protect the power system from faults or overloads

3.4.1.1. POWER SPECIFICATIONS

Note: The wire sizes listed are the sizes that the installed terminals will accept. Actual wire size used will be determined by the model's kVAR load. See Section 6.1 for more guidance.

Table 3-1: Power Field Wiring Connections

TERMINAL	FUNCTION	MODEL	ELECTRICAL SPECS	MIN WIRE SIZE	MAX WIRE SIZE	TORQUE
AC Input L1, L2, L3	AC Power Input	PFC-2Y3	208-230 VAC, 9 A	14 AWG	6 AWG	13 in-lbs
		PFC-2D10	208-230 VAC, 26 A	8 AWG	6 AWG	13 in-lbs
		PFC-2H12	208-230 VAC, 30 A	8 AWG	6 AWG	13 in-lbs
		PFC-4Y10	460-480 VAC, 12.5 A	14 AWG	6 AWG	13 in-lbs
		PFC-4D30	460-480 VAC, 37.5 A	8 AWG	6 AWG	13 in-lbs
		PFC-4D60	460-480 VAC, 75 A	4 AWG	2 AWG	120 in-lbs
GND	System Ground			12 AWG	6 AWG	150 in-lbs

3.4.1.2. SOURCE CONSIDERATIONS

PFC modules should be installed on a dedicated circuit breaker or fuse sized to the load of the PFCs. They should be installed as close to the point of use as possible to achieve the best effect. The PFCs can be

distributed through the electrical system as needed, or placed on the main breaker assembly.

Most local codes require conductors and breaker sizes to be oversized by 135% to allow for the reactive currents.

Check local code requirements for further information on this point. See the Engineering Data for further information on placement and sizing.

3.4.1.3. GROUNDING REQUIREMENTS

The PFC modules should be grounded in accordance with local electrical codes with the ground terminal provided.

3.4.2. CONTACTOR TERMINAL SPECIFICATIONS (IF SO EQUIPPED)

16 AWG to 8 AWG wire should be used at the contactor coil terminal block for all PFC models with an integrated contactor. Connection should be torque to 12 in-lbs. See Table 2-3 for coil voltages.

3.5. TYPICAL CONFIGURATIONS

- The Power Factor Correction Capacitors can be installed in several locations, each of which provides different benefits and considerations. See the Application Notes in Section 7 for an explanation of the benefits of each of these installations.
- The capacitors can be attached in parallel to allow for higher power factor correction. Refer to the Application Notes in Section 7 for more information on the benefits of different installations.

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4. OPERATION

4.1. FUNCTIONAL DESCRIPTION

The Bonitron PFC modules are intended to correct lagging power factor caused by motors and other inductive loads. They have three configurations to allow for increased filtering or better load matching.

See the Application Notes in Section 7 for more information on the benefits of the various features.

4.2. FEATURES

4.2.1. DELTA CONFIGURATION

The Delta Connection allows for the most power factor correction for a given footprint. This can be used to offset larger inductive loads.

4.2.2. WYE CONFIGURATION

Wye Configuration is used for lower VAR requirements, and has the added benefit of providing some low frequency common mode noise filtering.

4.2.3. HYBRID CONFIGURATION

Hybrid units have Power Factor Correction Capacitors connected in both Delta and Wye configurations to allow for larger VAR correction as well as the low frequency common mode noise filtering.

4.2.4. HIGH FREQUENCY FILTERING

All Bonitron PFC modules incorporate high frequency filter capacitors to allow for some protection from high frequency switching noise.

4.2.5. MOVs

All Bonitron PFCs incorporate delta connected metal oxide Varistors to protect the Power Factor Correction Capacitors from instantaneous high voltage noise caused by switching transients and other electrical anomalies.

4.2.6. INDICATORS

The PFC front panel has LEDs that indicate the condition of each leg of the power factor correction module. All LEDs should be lit during normal operation, and indicate that the PFC has power to all incoming power legs and is operating properly.

4.2.7. DISCHARGE RESISTORS

The integral Discharge Resistors are designed to discharge capacitors down to 75V or less within 60 seconds. Once power is removed from the units, allow at least three minutes before attempting service on the capacitor units.

4.2.8. CONTACTOR OPTIONS

The integrated contactor options allows the PFC to be switched on and off with high inductive loads. This allows the PFC to be applied only when needed to avoid an overall system loading power factor.

4.3. STARTUP

4.3.1. PRE-POWER CHECKS

Once the PFC unit has been mounted and wired to a dedicated overcurrent protection device, the wiring should be checked for proper connection and the terminals checked for proper torque.

Check that the voltage matches the unit that is installed.



WARNING!

- *Applying improper voltage to the unit can cause catastrophic failure of the capacitors.*
- *Close and secure the cover of the PFC module before applying power.*

4.3.2. CONTACTOR OPTION

If the PFC is equipped with a contactor, the contactor coil must be energized in order for the PFC to power on. Once the coil is energized, proceed to Section 4.3.3 Startup Procedure and Checks.

4.3.3. STARTUP PROCEDURE AND CHECKS

Once the connections and incoming voltage have been verified, apply power to the Power Factor Correction capacitors, and insure that the front panel LEDs are all lit.

Use a current meter to verify that all legs of the supply are carrying current that is close to the rated current listed in the Engineering data for the individual model.

If either of these conditions is not met, turn off power **immediately** and refer to Troubleshooting in Section 5.2 for further assistance.

4.4. OPERATION

Once the PFC modules are installed, there are no adjustments necessary. The cover indicators should be checked periodically to insure they are still all on.

The integral discharge resistors are designed to discharge capacitors down to 75V or less within 60 seconds. Once power is removed from the units, allow at least three minutes before attempting service on the capacitor units.



WARNING!

- *Once power is removed, the unit can still retain lethal voltages! Insure that the capacitors are discharged before attempting service.*
- *Close and secure the cover of the PFC module before applying power.*

5. MAINTENANCE AND TROUBLESHOOTING

There are no user serviceable parts in the PFC modules. Repairs or modifications to this equipment are to be performed by Bonitron approved personnel only. Any repair or modification to this equipment by personnel not approved by Bonitron will void any warranty remaining on this unit.



- *Once power is removed, the unit can still retain lethal voltages! Insure that the capacitors are discharged before attempting service.*
- *Close and secure the cover of the PFC module before applying power.*

5.1. PERIODIC TESTING

The Bonitron PFCs are designed to operate for up to 10 years without service.

5.2. TROUBLESHOOTING

5.2.1. LED INDICATORS NOT LIT

If the indicators on the front panel are not lit, first check the incoming voltage to the capacitor bank and incoming fuses or circuit breakers. Second, if supplied with a contactor, ensure that the appropriate voltage is supplied to the contactor coil and that the contactor is closed.

If the voltage is in the nominal operating range of the capacitor bank, the bank may require service or repair. Contact Bonitron for further assistance.

5.2.2. TRIPPING CIRCUIT BREAKERS OR BLOWN FUSES

If the overcurrent devices continually trip, verify that they are the proper size for the unit.

Check the amount of current going to the capacitors. If the current for that model is within the nominal range shown in the Engineering Data chart in Section 6, make sure the overcurrent or overload device is the proper size for the capacitors used. Also, please see "High Current" below.

Fast switching of the capacitors can also cause over-currents. When the capacitor bank is turned off, they remain charged at the voltage level of the incoming voltage, and will need time to discharge through the internal resistors. If the capacitor bank is switched back on before the bank is discharged, the incoming voltage can be at a reverse voltage of the capacitor, and will cause very high inrush currents during the first cycle. This can cause sensitive overcurrent devices to trip or blow. Always allow time for the capacitors to discharge before reenergizing the bank.

5.2.3. HIGH CURRENT

If you see sustained high currents going to the capacitor bank, with RMS values above 130% or peak currents above 170% of nominal for the model installed, there may be excessive harmonics or resonance in the system.

Use a power quality meter to determine the system has high harmonic content, or if the capacitor bank is causing system resonance.

Do not operate the capacitor bank with high currents, as the capacitor bank may overheat and fail prematurely.

Capacitor banks are more likely to cause system resonance if the system is lightly loaded, or there isn't enough system inductance to require correction. If this is the case, consider switching the capacitors in only when the associated motor load is running.

5.2.4. LOW CURRENT

Low currents can be caused by low system voltage. Check the incoming system voltage and match it to the amount of nominal current in the engineering data chart in Section 6.

It is also possible that there is a blown fuse or overcurrent device upstream of the capacitor bank. Insure that these devices are operating properly.

If the cap bank has been subjected to high current, voltage or temperature, the internal pressure disconnects may have operated.

- Power off the PFC.
- Wait for the caps to drain.
- Inspect the tops of the capacitors.
 - If bulged, PFC may be damaged and need replacement.

6. ENGINEERING DATA

6.1. RATINGS CHARTS

Table 6-1: 208 VAC System Voltage

MODEL NUMBER	CONTACTOR CONTROL VOLTAGE	DIMENSIONS (H" x W" x D")	CONNECTION TYPE	kVAR	MOTOR HP	LINE CURRENT	BREAKER SIZE	MIN WIRE SIZE	WATT LOSS
PFC-2Y3	N/A	12 x 12 x 6	Wye 4W+G	2.4 kVAR	7.5	8A	20A	14	1
PFC-2Y3-DC24	24VDC	12 x 12 x 6							
PFC-2Y3-AC120	115 - 120VAC								
PFC-2Y3-AC240	230 - 240VAC								
PFC-2Y3-AC480	460 - 480VAC								
PFC-2D10	N/A	12 x 12 x 6	Delta 3W+G	8.1 kVAR	30	23A	40A	8	4
PFC-2D10-DC24	24VDC	12 x 12 x 6							
PFC-2D10-AC120	115 - 120VAC								
PFC-2D10-AC240	230 - 240VAC								
PFC-2D10-AC480	460 - 480VAC								
PFC-2H12	N/A	12 x 12 x 6	Hybrid 4W+G	9.3 kVAR	40	26A	40A	8	4
PFC-2H12-DC24	24VDC	14 x 12 x 6							
PFC-2H12-AC120	115 - 120VAC								
PFC-2H12-AC240	230 - 240VAC								
PFC-2H12-AC480	460 - 480VAC								

Table 6-2: 230 - 240VAC System Voltage

MODEL NUMBER	CONTACTOR CONTROL VOLTAGE	DIMENSIONS (H" x W" x D")	CONNECTION TYPE	kVAR	MOTOR HP	LINE CURRENT	BREAKER SIZE	MIN WIRE SIZE	WATT LOSS
PFC-2Y3	N/A	12 x 12 x 6	Wye 4W+G	3.3 kVAR	10	9A	20A	14	1
PFC-2Y3-DC24	24VDC	12 x 12 x 6							
PFC-2Y3-AC120	115 - 120VAC								
PFC-2Y3-AC240	230 - 240VAC								
PFC-2Y3-AC480	460 - 480VAC								
PFC-2D10	N/A	12 x 12 x 6	Delta 3W+G	11 kVAR	50	26A	40A	8	5
PFC-2D10-DC24	24VDC	12 x 12 x 6							
PFC-2D10-AC120	115 - 120VAC								
PFC-2D10-AC240	230 - 240VAC								
PFC-2D10-AC480	460 - 480VAC								
PFC-2H12	N/A	12 x 12 x 6	Hybrid 4W+G	12.4 kVAR	50	30A	50A	8	6
PFC-2H12-DC24	24VDC	14 x 12 x 6							
PFC-2H12-AC120	115 - 120VAC								
PFC-2H12-AC240	230 - 240VAC								
PFC-2H12-AC480	460 - 480VAC								

Table 6-3: 460 - 480VAC System Voltage

MODEL NUMBER	CONTACTOR CONTROL VOLTAGE	DIMENSIONS (H" x W" x D")	CONNECTION TYPE	kVAR	MOTOR HP	LINE CURRENT	BREAKER SIZE	MIN WIRE SIZE	WATT LOSS
PFC-4Y10	N/A	14 x 12 x 8	Wye 4W+G	10.4 kVAR	40	12.5A	30A	14	5
PFC-4Y10-DC24	24VDC	14 x 12 x 8							
PFC-4Y10-AC120	115 - 120VAC								
PFC-4Y10-AC240	230 - 240VAC								
PFC-4Y10-AC480	460 - 480VAC								
PFC-4D30	N/A	14 x 12 x 8	Delta 3W+G	30 kVAR	125	37.5A	50A	8	14
PFC-4D30-DC24	24VDC	14 x 12 x 8							
PFC-4D30-AC120	115 - 120VAC								
PFC-4D30-AC240	230 - 240VAC								
PFC-4D30-AC480	460 - 480VAC								
PFC-4D60	N/A	14 x 12 x 8	Delta 3W+G	60 kVAR	250	75A	100A	4	27
PFC-4D60-DC24	24VDC	16 x 14 x 8							
PFC-4D60-AC120	115 - 120VAC								
PFC-4D60-AC240	230 - 240VAC								
PFC-4D60-AC480	460 - 480VAC								

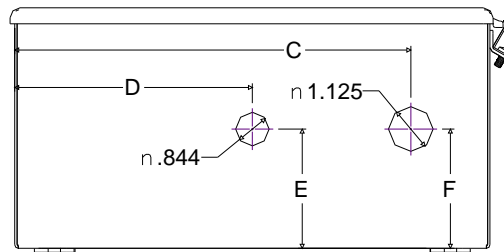
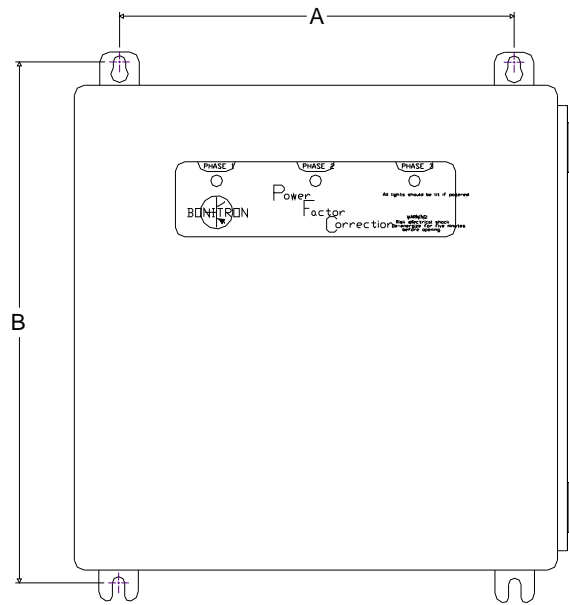
Notes:

1. Motor Horsepowers are recommendations only. Your particular installation may require more or less kVAR for proper correction.
2. Most local codes require conductors and breaker sizes to be oversized by 135% to allow for the reactive currents. Check local code requirements for further information.

6.2. CERTIFICATIONS

Models shown in **bold** type in Tables 6-1, 6-2, and 6-3 are UL listed under file number E317357.

6.3. DIMENSIONS AND MECHANICAL DRAWINGS



DIMENSIONS	A	B	C	D	E	F
PFC-243	10	12.8	10	6	3	3
PFC-2H12	10	14.8	10	6	3	3
PFC-2D10	10	12.8	10	6	3	3
PFC-4Y10	10	15.25	10	6	4	4
PFC-4D30	10	15.25	10	6	4	4
PFC-4D60	12	16.75	10.5	7	5.5	5.5

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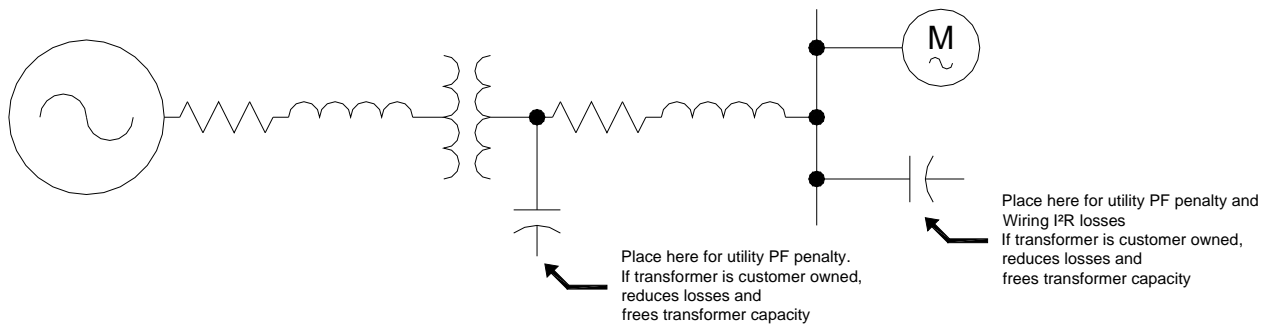
7. APPENDICES

7.1. APPLICATION NOTES

7.1.1. PLACEMENT AND CONFIGURATION

Placement of the Power Factor Correction Capacitors can allow for additional savings. Placing the capacitors as close to the load as possible will reduce the reactive currents in the most conductors, and should be used when practical.

Figure 7-1: Placement and Configuration



7.1.1.1. POWER GRID CONNECTION

Connecting the PFCs to the power grid will allow for power factor reduction. This will also reduce the reactive currents in the transformers upstream of the PFCs, and if these transformers are owned by the customer, can allow for greater real loads to be attached to the transformer without overloading.

Figure 7-2: Power Grid Connection



The PFCs installed in this position can be switched in and out as required, or installed as a permanent static bank.

7.1.1.2. CONNECTION AT MOTOR

Connection close to the motor allows for the most benefit, as the reactive currents will flow through the least amount of conductors. This also allows for the power factor correction benefit, as well as the reduced load on all upstream transformers.

The PFCs can be switched with the motor to reduce the possibility of there being too much power factor correction on a facility, causing a leading power factor penalty or system resonance.

7.1.1.2.1. DEDICATED CONTACTOR

In this configuration, the motor and capacitor have separate contactors.

This method avoids the possibility of mutual excitation, and can also be used in installations where the capacitor cannot be installed below the motor contactor. The capacitor can be switched in either with the same signal as the motor, or with a current sensor on the motor leads.

Figure 7-3: Dedicated Contactor with Same Signal as Motor

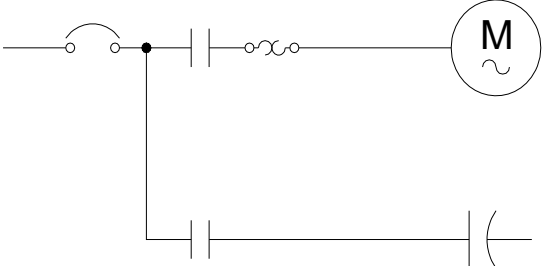
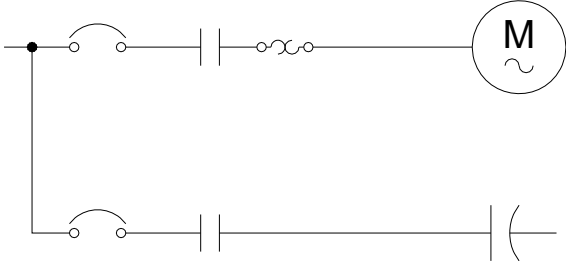


Figure 7-4: Dedicated Contactor and Separate Overload



7.1.1.2.2. CONNECTION WITH A SOFT START CONTROLLER

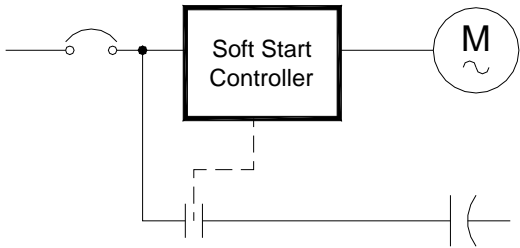
PFCs can be used with motors that use Soft Start Controllers; however they must be placed on a dedicated contactor that is only closed when the motor is at full speed.

Soft starters use phase controlled SCRs to ramp the motor voltage up. This causes no problems with the inductive motor load, but causes major problems with capacitive loads.

If the contactors are placed below the soft starter, the PFCs below will draw large currents during the startup portion, and can cause catastrophic damage to the soft starter or capacitors.

Most soft starters have an output that can be monitored to turn the capacitor bank on when the soft start is through the ramp up of the motor, and attached across the line.

Figure 7-5: Soft Start Controller Connection



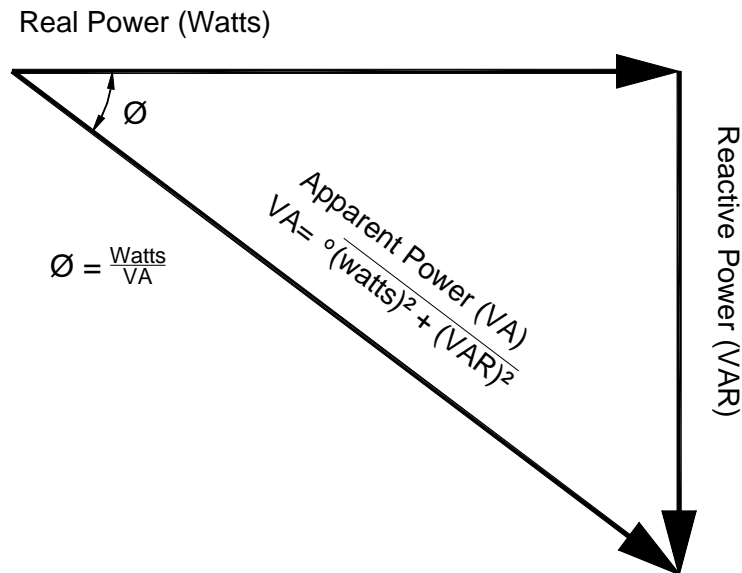
7.1.2. POWER FACTOR

All electrical loads require power. Most heating and lighting loads are purely resistive, meaning that the power delivered to them results in conversion to work, as measured in watts.

Other loads, such as motors, inductive heaters, and lighting ballasts require reactive power to operate. This reactive power is used to magnetize the cores of the transformers, coils, rotors, and stators of the attached loads. These currents do not perform actual work, and therefore are not included in the power delivered as watts. These loads are referred to as reactive loads, and shift the phase of the current with respect to the incoming voltage. The amount of phase shift is determined by the amount of reactive power required by the load.

Power factor is defined as the ratio between total or apparent power measured in VA and real power measured in watts. The "Power Triangle" below shows this graphically. (Figure 7-8)

Figure 7-6: Power Triangle



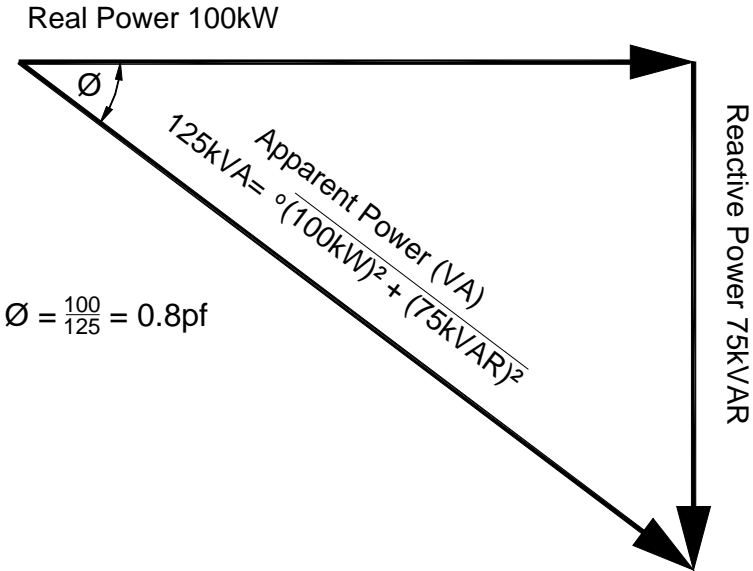
The power factor is the cosine of the angle between these two vectors.

Low power factors indicate that a large amount of total power is required for a given amount of work performed by the motors or other connected loads.

Motors and other inductive loads have a power factor that is "lagging". Capacitors have a power factor that is "leading". Poor lagging power factor can be corrected or cancelled out by attaching enough capacitors to offset the lag of the inductive loads with the lead of the capacitors. This allows power to be stored in the capacitors that is then transferred to the inductive load as the input AC waveform falls to allow for a reduction in the total input or apparent power to the system.

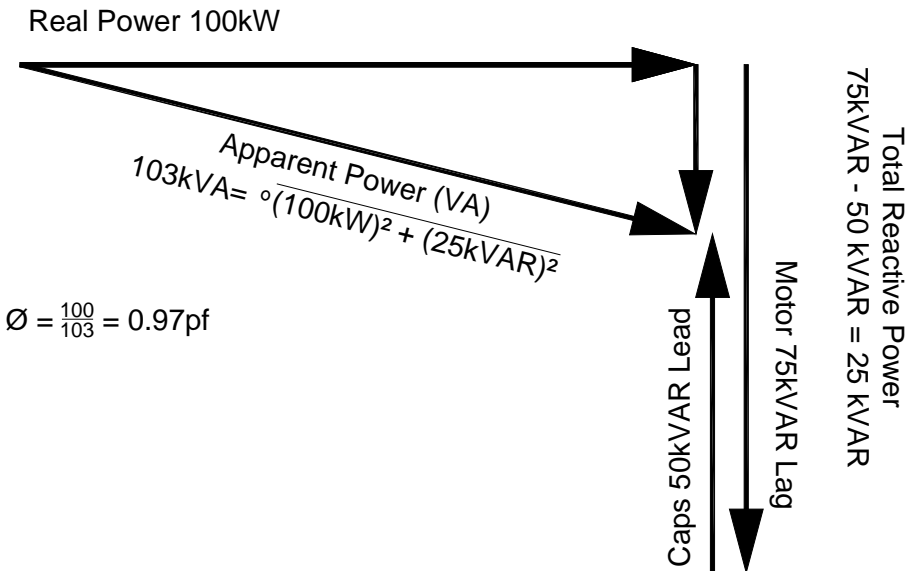
For example, a motor load that needs 100kW and 75kVAR (lagging) to operate would look like Figure 7-9.

Figure 7-7: Motor Load Example 1



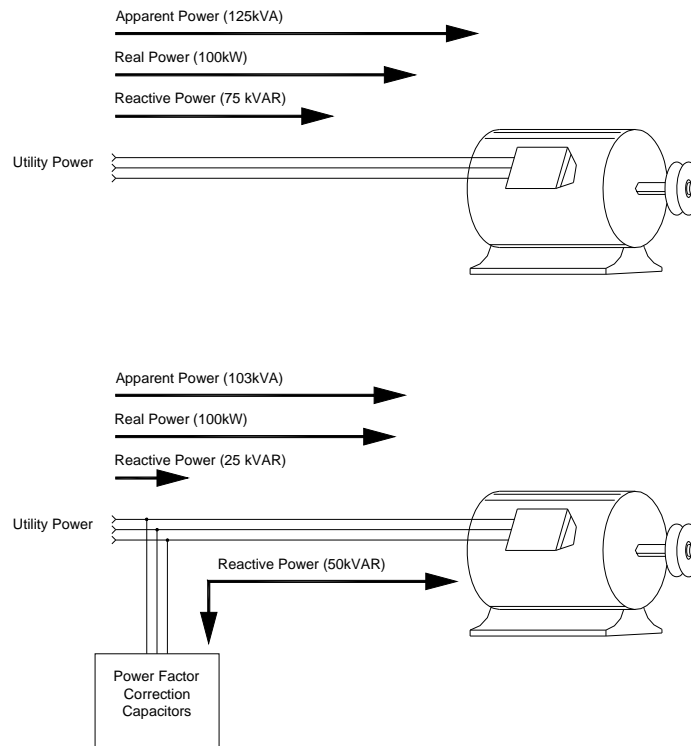
When 50kVAR (leading) of power factor correction is applied, the total kVAR in the system is 25kVAR.

Figure 7-8: Motor Load Example 2



Note that these reactive currents still flow in the power system, but the system requires less total or apparent power to operate. Refer to Figure 7-11.

Figure 7-9: Reactive Current Flow



Correcting power factor does not reduce the watts consumed by the system as the same amount of work is being performed, but it does reduce the total power required from the utility and the power grid.

7.1.3. VA POWER REDUCTION AND REDUCING BILLS

Higher power factors, or power factors closer to 1.0 reduce the amount of power required from the utility, and based on the billing system applied to a location, can significantly reduce the power bill for the facility.

Some billing systems charge for kVA/hours, and as described above, the amount of kVA or apparent power consumed by the power factor corrected facility is lower than one without.

Demand charges can also be reduced, as the kVA required during peak periods can be reduced.

Some areas apply a “power factor penalty” charge that is directly related to the power factor of a facility.

Because billing systems vary from area to area, you may use the sizing data below to estimate your potential power reduction, and then examine your current power bill to determine your potential savings.

Power factor correction with capacitors is only useful in correcting inductive loads, such as motors. The amount of correction required will be determined in part by the amount of motor load in your facility. Your potential savings will be directly related to the percentage of motor load in your facility.

Contrary to popular myth, local power companies can be quite helpful in

determining the potential for a lower power bill to your facility, and can assist with explaining your billing structure and how it can be affected by power factor correction.

7.1.4. I²R LOSSES AND OTHER POTENTIAL SAVINGS

As explained above, the reactive currents continue to flow within the power grid between the inductive load and the power factor correction capacitors.

These currents place an extra load on the conductors and buswork between the two loads. If the power factor correction capacitors are physically far away from the inductive load, the current flows through more buswork and wiring within the power grid of the facility. Because there is resistance in these conductors, some of the power is expended as heat in these conductors. This heat is power that is actually wasted, and can be reduced if the power factor correction capacitors are installed as physically close to the inductive load as possible.

This can allow for a further 1-2% of power savings in those circuits, based on the resistance of the supply network and distance.

This bus and conduit heating does add to the heat load of a facility, and although may be small, can have an impact on the cooling required for the facility. These savings are more difficult to quantify.

It is also possible that the electrical equipment involved may run cooler due to the reduced total current in the buswork and transformers, and could extend the life of the equipment.

7.1.5. SIZING

There are two reliable ways to size power factor correction capacitors. If the power factor is known, the amount of correction VARS required can be determined from a chart. The power factor can be measured directly with a power meter either at the service entrance or at the individual load.

Correction size can also be determined by the horsepower of the motors to be corrected using the chart below. Keep in mind that these are recommended values determined from standard NEMA rated motors, and may be different for your particular motors.

In either case, the total power factor correction capacitance added should be less than 20% of the total capacity of the upstream transformer to avoid resonance.

7.1.6. RESONANCE

Resonance occurs in systems that have reactive elements that can have large currents flowing between them due to a driving electrical load at the same frequency as the natural frequency of the reactive elements. The resonant frequency is determined by the total reactive impedance of the system. In practice, this frequency can be difficult to determine. If the natural resonant frequency is the same as a harmonic being produced in the system, the resonance can cause the currents to rise in the grid to the point where the overcurrent and overloads begin to happen. This can also cause overheating in the capacitors, transformers, and other elements of the power system.

Resonance can be avoided by limiting the amount of power factor correction

capacitors installed, and by insuring that as the motor loads are reduced, the amount of capacitance is reduced. The best way to do this is to connect the capacitors at the point of load, and switch them in and out with the motor being corrected.

7.1.7. HARMONICS

Harmonics are sinusoidal voltages and currents with frequencies that are multiples of a 50 Hz or 60 Hz power supply frequency. Harmonics result from the operation of electrical loads with non-linear voltage-current characteristics.

Harmonics are mainly caused by loads operated with modern electronic devices, such as converters, electrical drives, welding machines, and uninterruptible power supplies (UPS).

Because the capacitors are effectively low pass filters, they provide a low resistance path for these higher frequencies, and can actually “attract” these harmonics, causing high currents to flow to the capacitors through the associated conductors. This is indicated by higher than expected RMS currents.

Ensure that the current through the capacitor does not exceed 1.3 times the rated current.

This may indicate heavy presence of harmonics. Check the voltage and current using a true RMS multi-meter.

Ensure that the RMS voltage doesn't exceed 1.1 times the voltage rating and the peak voltage doesn't exceed 1.6 times the voltage rating. Use a true RMS and peak voltmeter or oscilloscope to check the incoming voltage.



Only power capacitors with reactors – namely de-tuned capacitor banks – should be used in applications with harmonic distortion. Depending on the chosen series resonance frequency, a part of the harmonic current will be absorbed by the power capacitor. The rest of the harmonic current will flow into the grid. The use of power capacitors with reactors reduces harmonic distortion and minimizes the disturbing effects on operation of other loads.

Avoid resonance conditions. The most important reason for installing de-tuned capacitor banks is to avoid resonance conditions. Resonance conditions may multiply existing harmonics, create power quality problems, and damage distribution equipment.

Occurrences of resonance should by all means be avoided by appropriate application design!

Total RMS capacitor current (including fundamental and harmonic currents) specified in the technical data of the specific series must never be exceeded.

7.1.8. SWITCHING CAPACITORS

Switching LV PFC capacitors can cause high inrush currents of more than 200 times the rated current, especially when they are connected in parallel to others that are already energized. This may cause additional stress to contactors as well as to capacitors and reduce their life cycle.

Inrush currents have a negative effect on power quality, e.g. transients, or voltage drop. Bonitron Power Factor Correction Capacitors feature high impulse handling capability.

For switching capacitors, inrush current limitation is required, e.g.: contactors with pre-charging resistors for pre-loading of capacitors or serial air coils (approx. 8 turns in the connection cables between contactor and capacitor with a diameter of 10 cm)

Using standard contactors or relays may not be able to handle the high inrush currents caused by the capacitors, and may fail due to arcing during switching.

7.1.9. OVERPRESSURE DISCONNECTOR

Electrical components do not have unlimited life expectancies; this also applies to self-healing capacitors. As polypropylene-type capacitors seldom produce a pronounced short circuit, HRC fuses or circuit breakers alone do not offer sufficient protection.

All Bonitron Power Factor Correction Capacitors are fitted with a disconnecter that responds to overpressure. If numerous electric breakdowns occur at the end of life or as the result of thermal or electric overload (within IEC 831 specification), the formation of gas causes the pressure inside the capacitor case to rise.

This causes a change in length because of curvature of the lid or stretching of the expansion bead. Expansion beyond a certain degree will separate the internal wires (tear-off fuses) and disconnect the capacitor from the line.

These overpressure disconnectors are internal devices that require no service.

7.1.10. LIFETIME

Bonitron PFC Power Factor Correction Capacitors are designed to last ten years of constant operation under proper conditions.

This lifetime can be shortened significantly if operated above the current rating or above the rated temperature.
