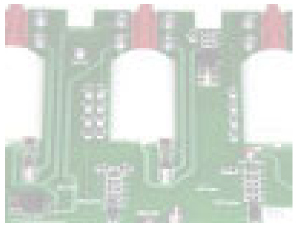
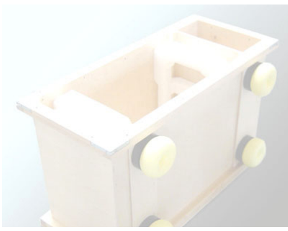
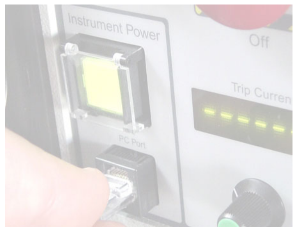
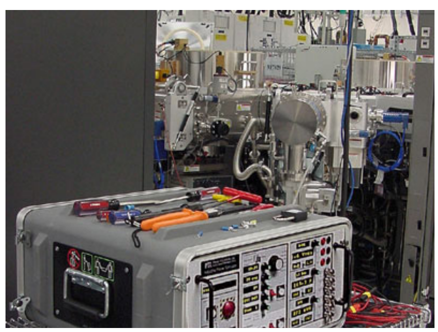
Advanced Test Equipment Corp.
www.atecorp.com 800-404-ATEC (2832)

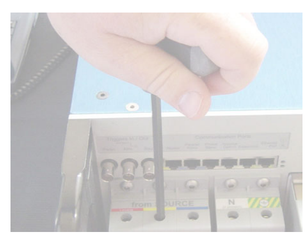
Power Standards Lab
1201 Marina Village Parkway #101
Alameda, California 94501 U.S.A.
TEL ++1-510-522-4400
FAX ++1-510-522-4455
www.PowerStandards.com

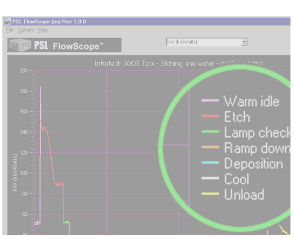
Industrial Power Corruptor®
User's Manual

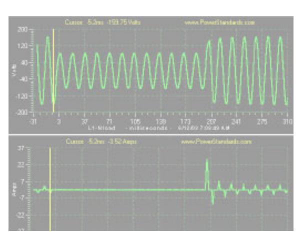


IPC-480V-200A
IPC-480V-100A
IPC-480V-50A
IPC-240V-25A



Manual Revision 1.00




WARNING: Death, serious injury, or fire hazard could result from improper connection or operation of this instrument. Carefully read and understand manual before connecting this instrument.

AVERTISSEMENT: Si l'instrument est mal connecté, la mort, des blessures graves, ou un danger d'incendie peuvent s'en suivre. Lisez attentivement le manuel avant de connecter l'instrument.

WARNUNG: Der falsche Anschluß dieses Gerätes kann Tod, schwere Verletzungen oder Feuer verursachen. Bevor Sie dieses Instrument anschließen, müssen Sie die Anleitung lesen und verstanden haben.

ADVERTENCIA: Una conexión incorrecta de este instrumento puede producir la muerte, lesiones graves y riesgo de incendio. Lea y entienda el manual antes de conectar.

Printed in the United States of America.
First Printing: June 2003

SYMBOL TABLE

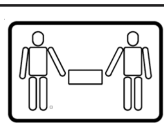
Symbol	Meaning
	Caution. Refer to this manual.
	Caution. Risk of electric shock.
	Fuse. Replace only with indicated rating and type.
	Alternating current
	Protective conductor terminal (earth)
	Heavy. Risk of injury. Do not attempt to lift by yourself.
	Heavy. Use cart to transport.
	Heavy. Lift with a partner.

Table of Contents

1.1 What is an Industrial Power Corruptor?

An Industrial Power Corruptor produces bad quality electric power, reliably and repeatedly.

Power from a clean source, such as your electric company, passes through your IPC. Your IPC then adds disturbances - sags, swells, interruptions, etc. - that reproduce disturbances that occur in the real world. You use this disturbed power to test your equipment, to verify that your equipment is rugged enough to tolerate power disturbances.

Because all power for your equipment passes through your IPC, you can use its optional Power Flow Analysis package to measure and record all of your electric power parameters, including inrush current, kWh, power factor, etc.

Your IPC includes many tools that make it easier to diagnose power disturbance problems, including a 31-channel digital oscilloscope, many pre-connected meters, and a waveform display program that zooms, converts to true-RMS, and has graphs that you can copy and paste into reports.

The optional Power Flow Analysis package adds a real-time spectrum analyzer, harmonics meters, power flow meters, and a superb power flow recorder for analyzing energy consumption of your load.

Although your IPC has many safety features, such as ground current detection, overtemperature sensors, overvoltage sensors, and overcurrent breaker trips, testing with electric power is always dangerous. Do not operate your IPC unless you have the training and skill to do so. Be careful.

Use your IPC to verify that your sensitive electronic equipment can tolerate power disturbances.

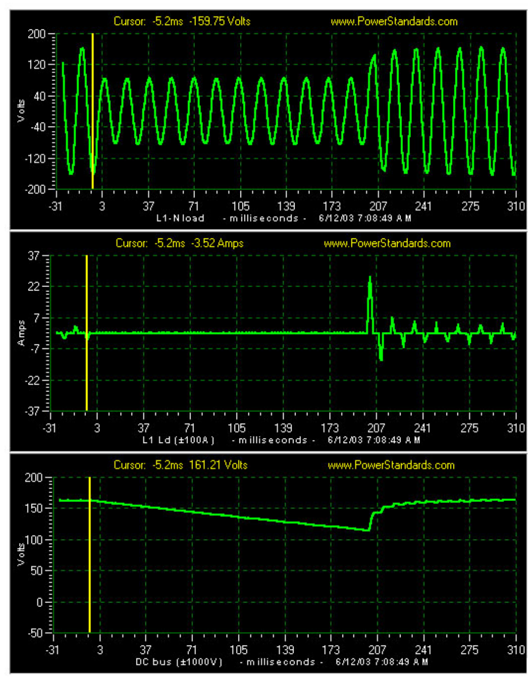
1.2 What is a voltage sag?

A voltage sag, or dip, is a brief reduction in RMS voltage on an AC power circuit. Typically, a voltage sag duration is between one cycle and a few seconds; longer events are usually called "undervoltages".

Common causes of voltage sags include distant faults, or short circuits, on a utility power grid; sudden, large increases in current, typically caused by a motor starting or a large electronic load being connected; and voltage regulation faults.

Voltage sags can disrupt sensitive electronic equipment in four different ways. First, there may not be enough energy available during a voltage sag to continue to operate all, or part of, the equipment. Second, a circuit within the equipment may detect the voltage sag and consequently decide to shut down the equipment, whether that action is appropriate or not. Third, a voltage sag on one phase of a three-phase system can trip phase unbalance or phase rotation relays. And fourth, the end of the voltage sag often involves a rapid increase in line voltage, which can inadvertently trip the equipment's "power-on-reset" circuits.

These are difficult problems to diagnose, because they happen at random times, and they are generally very brief. The symptom is often simply that the sensitive equipment misbehaves, or malfunctions, for no apparent reason.



A typical voltage sag, generated by the IPC. The top graph shows the voltage waveform. The middle graph shows the current drawn by the load. The bottom graph shows the load's internal DC bus, which collapsed during the sag. All of these graphs were recorded by the IPC's internal data acquisition system.

1.3 What is a voltage swell?

A voltage swell is the opposite of a voltage sag. It is a brief increase in RMS voltage on the AC power circuit. Although the negative impacts of small voltage swells are rare, certain types of equipment are highly susceptible to these fluctuations. As a result, some international standards also address these types of events.

1.4 Why generate sags and swells?

The simplest way to solve voltage sag and swell problems is to make your equipment immune to common voltage sag/swell events. And the simplest way to increase sag/swell immunity is to apply sags and swells of controlled depth and duration to the equipment, find out what goes wrong, and fix it.

Your IPC lets you provide poor quality power to your equipment under test. It can apply sags/swells of controlled depth and duration to your equipment, and records how your equipment responds.

1.5 Why use a multi-channel data acquisition system?

It isn't necessary to use a multi-channel data acquisition system during sag testing, but it helps.

If you simply need to verify that your sensitive equipment can tolerate a particular range of voltage sags, a data acquisition system is not necessary. Just apply the sags, and see if your equipment works.

However, if your equipment does misbehave, it is useful to know exactly what happened. Your IPC contains many channels of high-speed data acquisition. Some of these channels are permanently connected to ac power voltages and currents, but many of them are available for you to use any way you like.

You can use these uncommitted channels to monitor high voltages and low voltages inside your equipment. Common monitoring points include power supply outputs, emergency shutdown contacts, reset lines, and unbalance detection lines.

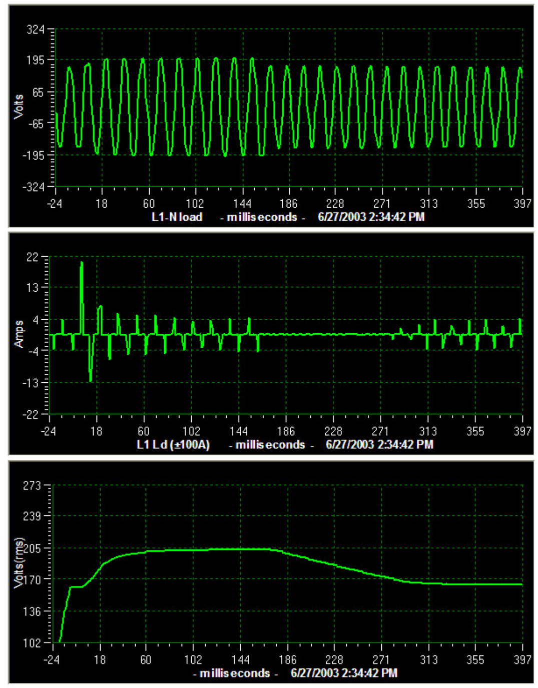
With the data gathered by your IPC data acquisition system, you will quickly determine how and why your equipment is misbehaving. A solution is often easy to design and install, and you can re-test to verify that you have, in fact, increased your voltage sag immunity.

1.6 Useful technical features of your IPC

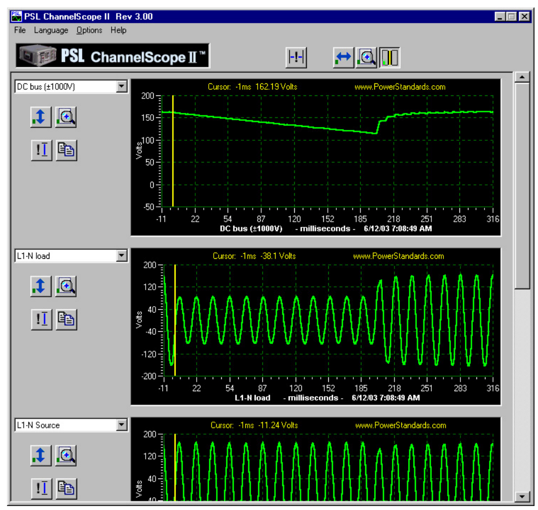
Your IPC sag swell generator is unique in that it has been designed to address a wide variety of testing applications, ranging from a quick test of a small power supply or relay, to a detailed study of a sophisticated and complex manufacturing tool.

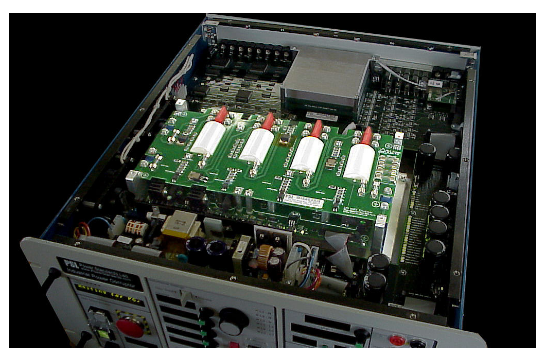
A patent-pending transformer design enables your IPC to generate voltage sags, swells, and interruptions, ranging from 0% to 125% of the nominal voltage.

A patent-pending power switching technology combines the best features of IGBT switches and electromechanical relays. This design allows for both gapless switching and long duration events.



A typical voltage swell, generated by the IPC. The top graph shows the voltage waveform. The middle graph shows the current drawn by the load. The bottom graph shows the response of the load's internal DC bus.





The IGBT module provides gapless switching during transitions.

True (not simulated) phase-to-phase sags and swells can be generated.

The front panel of your IPC is packed with an extensive array of control and monitoring functions. The Disturbance Settings section on the front panel lets you set depth, duration, angle, and phase settings for your event. It also allows you to select multiple steps in a predefined test recipe.

The three sets of front panel meters let you select which of the 30 channels of data you wish to display directly on the IPC. Each set of meters also includes displays for minimum and maximum reading.

There are 9 external analog input channels on the front panel of your IPC. Three of these channels are +/- 600V ac or dc, and the remaining 6 channels are +/- 100V ac or dc. These inputs can be extremely valuable when you attach them to various locations on the equipment being tested.

On the rear panel, your IPC has 9 channels of isolated, scaled, low-voltage outputs that you can connect to external data acquisition systems, such as strip chart recorders and oscilloscopes. This feature lets you externally monitor the voltage and current channels internal to the IPC. An output signal notifies your external system that a sag is about to begin.

The IPC main circuit breaker can be manually tripped using the large red mushroom switch. The trip current for this breaker can also be set using the Trip Current dial. For more information, see the Appendix.

1.7 Safety features of your IPC

Your IPC sag swell generator has many built-in hardware and firmware safety features:

The internal design and an integrated circuit breaker determines the maximum current rating or your IPC. You can, however, use the front panel dial to select a lower current to trip the breaker. This feature improves safety when testing a low current devices.

You can trip the circuit breaker manually using the large red mushroom switch on the front panel.

If you have the Motor Operator option installed, you can also reset the circuit breaker from the button on the front panel, rather than having to reach back to the high voltage area at the rear of your unit.

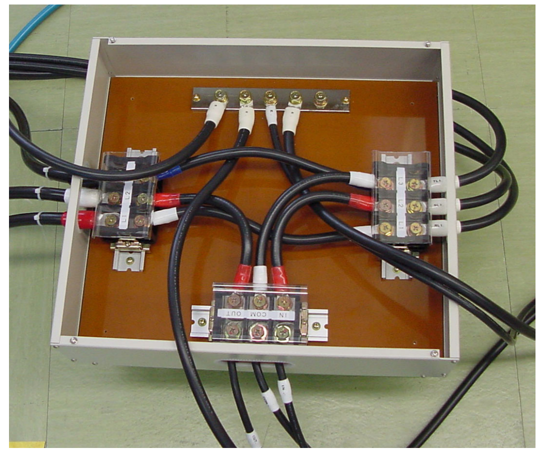
Your IPC continually monitors many internal conditions, both in standby and event mode. Voltage, current, transformer temperature, relay temperature, IGBT temperature, and ground current are just some of the variables that are continually monitored.

Depending on the severity of the fault state, your IPC will respond by tripping the breaker, halting or preventing an event, or just notifying you on the front panel display.

2.1 Testing equipment with your Industrial Power Corruptor

Use your Industrial Power Corruptor to test equipment that your have designed or purchased. You can test for immunity to voltage sags or swells, measure start-up current surges, and - with the IPC's Power Flow Analysis option - verify power factor, harmonics, and power consumption.

2.2 Pre-test preparation

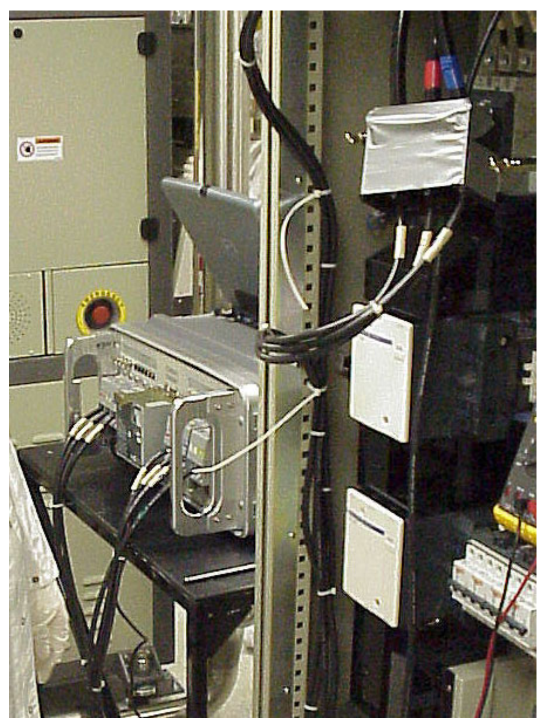


The wiring for inserting your IPC can be as simple as an extension power cord, broken in the middle, or as sophisticated as a formal junction box such as this one.

2.2.1 Preparing the equipment to be tested

Before you even connect your Industrial Power Corruptor, you should prepare the equipment that you want to test, which is commonly referred to as the Equipment Under Test or EUT.

1. Verify that your EUT is working properly. Run it through a complete operating cycle, and solve any operating problems.
2. Before doing any testing, write down what you mean by "Pass" and "Fail". For example, if your EUT misbehaves during a voltage sag but recovers, does it pass or fail? What if it shuts down, but can be re-started just by pushing a button? What if it continues to operate, but goes slightly out of spec? How far out of spec must it go to be a failure?
3. Gather all the details about the EUT: model number, serial number, nominal power requirements, etc. You will need this information for the setup form in the IPC software.
4. Gather all the information about the test participants. Again, you will need this information for the setup form.
5. Although it is unlikely, it is possible for the EUT (or materials being processed by the EUT) to be damaged during testing. Make sure that all participants understand the risks.
6. Determine how to shut power off for the EUT. Find a back-up method of shutting power off.
7. Prepare a way of inserting the IPC between the power source and the EUT. This may be as simple as an extension cord, cut in the middle, or it may be as formal as a carefully-wired junction box.
8. Designate a single individual who is responsible for safety. Make sure everyone involved in testing knows who it is. Follow that individual's instructions.



Whether testing high-power industrial equipment, or low-power benchtop equipment, always follow the same safety procedures.

2.2.2 Safety

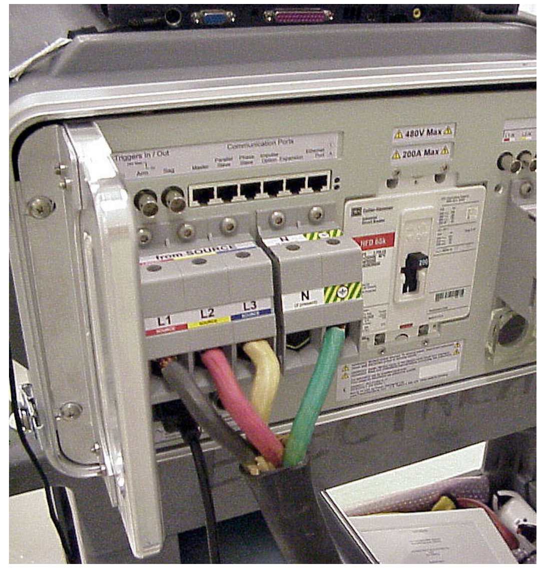
You are working with dangerous high voltage and high current. Follow industry-standard safety precautions. Do not connect your IPC unless you are qualified to do so.

The advice that follows does not supersede your own organization's safety standards. Local safety standards, and industry safety standards, take priority. The advice in this section is a supplement to industry and local safety standards.

It is a very good idea to prepare a written check-list. Use it every time you begin a new test.

Prior to connecting your IPC:

1. Verify exit locations.
2. Locate the nearest fire extinguisher.
3. Find the nearest telephone, and identify the emergency telephone number. Write down your location, and place the note near the telephone.
4. Determine what safety equipment is required: insulating mats, insulating gloves, goggles, hard hats, etc.
5. Determine what dangerous gases, liquids, or chemicals are present.
6. Determine what physical risks are present: falling objects, pinch points, etc.
7. Determine what alarms may sound during testing, and find out what the appropriate reaction is to each alarm.
8. Assign responsibilities to each member of the test team. Never test alone.
9. Make sure there is unobstructed access to an emergency power off location, upstream from your IPC location. Verify that each member of the test team knows where it is, and how to operate it.
10. Make sure there is unobstructed access to a secondary emergency power off location, upstream from the emergency power off location, and that each member of the test team knows where it is and how to operate it.
11. Verify the current limiting device ratings (circuit breaker or fuse), including the speed at which it operates.
12. Inspect the IPC. Do not use it if there is any visible damage, especially to the high voltage terminals. Do not use it if there are any rattles or loose connections.
13. Turn off and lock out the power source.
14. First verify that your multimeter works, by testing it on a live circuit. Then verify that there is no voltage between each pair of power conductors, and between each power conductor and earth.
15. Inspect each power conductor that will be used during the test. Is the power conductor cross-section adequate for the available current? Look for broken, nicked, cracked, or damaged insulation.
16. Make the power connections. Verify that all connectors are appropriately tight. Tug on each connection to verify it is mechanically secure. Mechanically anchor all power cables so that no physical strain can be placed on the connections during testing. Block physical access to any exposed wiring.
17. Have each member of the test team independently verify that the connections are correct prior to applying power. The final verification should be made by the individual responsible for safety.



2.2.3 Unpacking your Industrial Power Corruptor

Your IPC is a sensitive and calibrated piece of electronic test equipment. It is also heavy, which can lead to damage if not handled with extreme care. Your IPC is shipped to you in a custom wooden crate with supportive packing.

Do not discard the crate and packing material! Always use the crate, every time your IPC is shipped. If not transported in this manner, your IPC has no protection from vibration or shock.

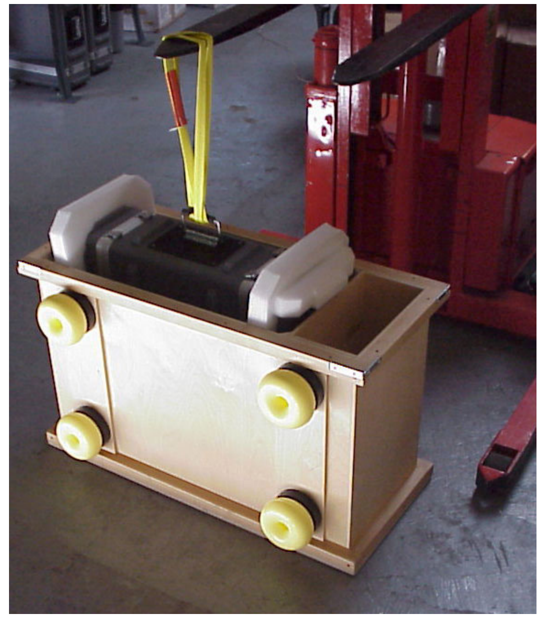
To remove your IPC from the crate, orientate the crate with the lid (with securing bolts) facing up.

Unscrew the wing nuts holding the lid in place.

Remove the lid, and then remove any accessories in the smaller side compartments. The compartment may be covered by a lid with a finger hole.

A lifting strap is provided. Loop this through the upper handle, and lift the IPC from the crate using a forklift or similar lifting device. Or orient the crate so that you can gently slide your IPC from the crate onto a flat surface.

If your IPC is to be hand-carried, ensure that two people lift the unit using the handles on the side of the case.



Your IPC weighs 130 lbs. (60kg). You can remove it from its crate with a forklift, or you can set the crate on its yellow feet and gently slide your IPC out horizontally.

2.2.4 Connecting instrument power

Plug the AC power cord (provided with your IPC) into the AC inlet, labeled "Instrument power", on the back of your IPC. Plug the other end into a 100 - 240Vac power source. Turn on your IPC with the front panel "Instrument Power" switch.

2.2.5 Connecting to your computer

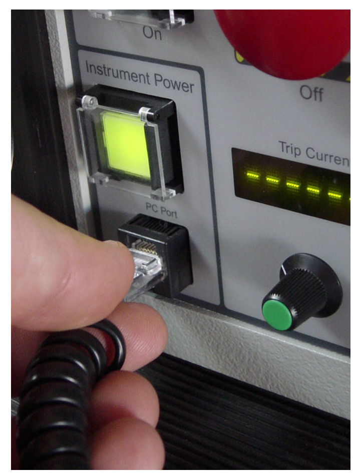
To operate your IPC you must first connect it to a computer running the IPC software.

If you have not yet loaded the IPC software (contained on the CD provided with your IPC), read and follow the instructions in the software section of this manual.

Find the RJ-45 jack, labelled “PC Port”, on the lower left of the front panel of your IPC.

Use the cable and adapter provided with your IPC to connect your IPC to the DB-9 serial port on your computer.

If your computer has a USB port, and no 9-pin serial connection, you will need a USB-Serial adapter. We recommend using a Belkin model F5U103.



Connect one end of the coms cable to the IPC PC Port on your IPC’s front panel, near the power switch. Connect the other end to the serial port on your computer using the 9-pin adaptor supplied. If your computer lacks a serial port, use a USB-to-serial adaptor (use Belkin model F5U103).

2.2.6 Connecting test power

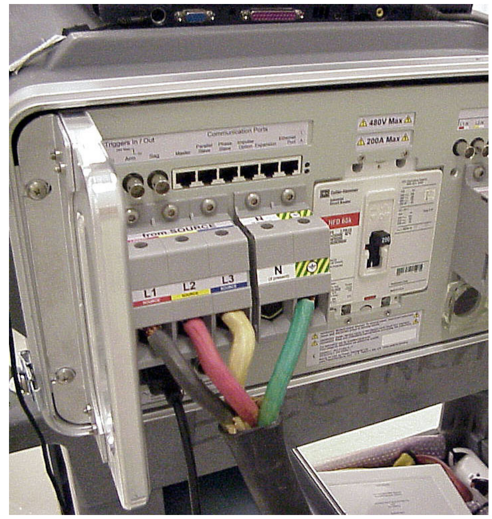
You will insert your IPC between your main source of power and the equipment you plan to test.

On the rear of your IPC, find the 10 large gray terminal blocks, five labelled “from SOURCE” and five labelled “to LOAD”.

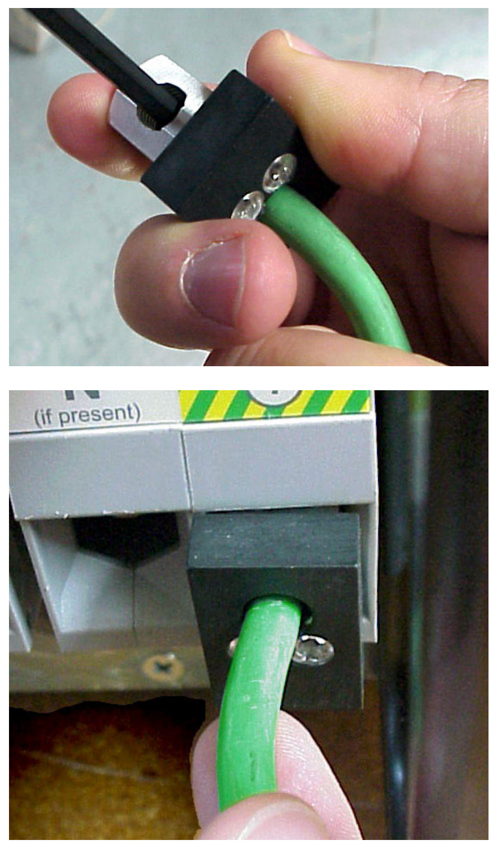
Use these terminal blocks to connect the source side power connections (conductors from your mains panel) and load side power connections (conductors to the equipment you plan to test).

You can connect single phase, three-phase delta, or three-phase Y power, depending on what your equipment under test (EUT) requires for operation. The terminal blocks are labeled for easy connection.

See following pages for single and 3-phase connection details.



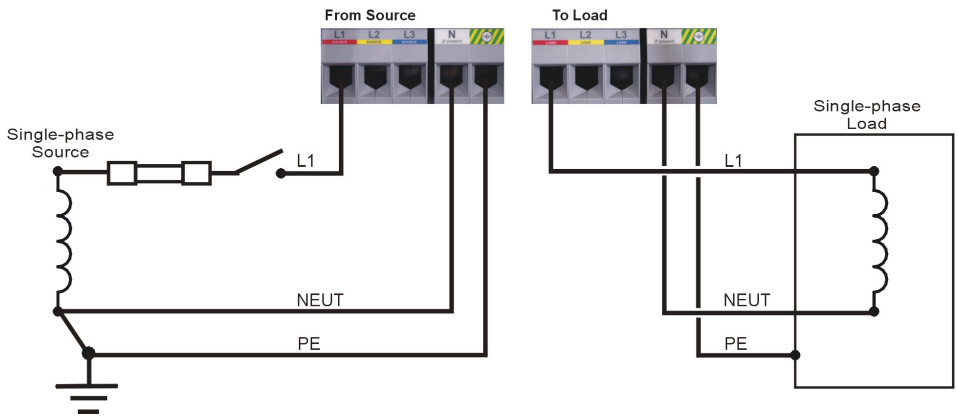
Typical three-phase source-side connections for a 3-phase delta system. The conductors are large enough to be securely captured by the gray terminal blocks.



If your conductors are smaller than 2AWG, use the provided wire size adapters. Insert the stripped wire (top) into the adapter, making sure that the set-screw clamps on the conductor, and that the insulation is fully inside the black insulating block. Then install the adaptor into the gray terminal block. Tug firmly on the wire to verify that it is mechanically secure.

2.2.6.1 Single-phase power connections

Warning: Death, serious injury, or fire hazard could result from improper connection of this instrument. The rear of the IPC is a high voltage, high current area. Follow industry standard safety precautions at all times. Do not make electric power connections unless you are qualified to do so. Do not operate this instrument until you have received appropriate training and are familiar with this entire manual.



Follow all local safety codes, practices, and requirements. They take precedence over the instructions here.

Always disconnect and lock out power before making or removing connections to your IPC.

Conductors to the source side terminal blocks of your IPC should be connected to a power source that is equipped with a disconnect switch, and with an appropriately sized current-limiting device (fuse or circuit breaker). Avoid lengthy conductors between this power source and your IPC; install your IPC as close as practical to this power source. Do not block access to the disconnect switch.

Always install protective earth conductors to both source-side and load-side protective earth terminal blocks with a cross section adequate to carry all available current.

All conductors connected to the IPC must be stranded, with insulation temperature rating of at least 105°C, a voltage rating equal to or greater than the voltage supplied, and of adequate cross-section for the available current.

Make sure that it is impossible for any person to touch any bare wires or terminal block contacts after you have made the terminations.

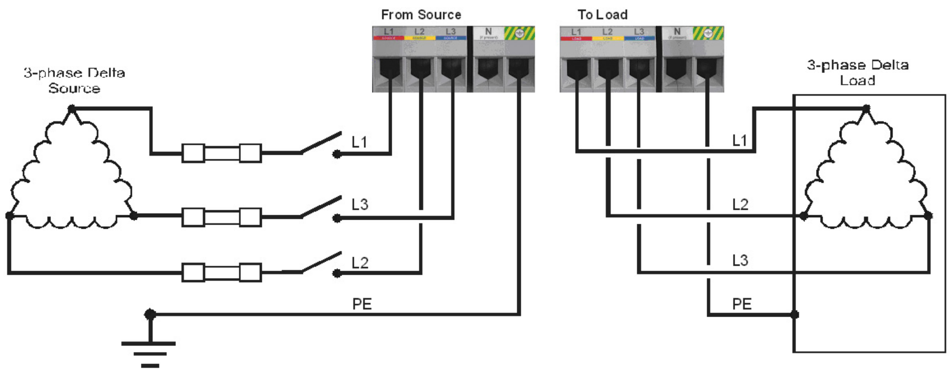
If you are using wire conductors smaller than #2AWG (34 mm^2), insert the conductor in a wire adaptor provided with your IPC, then insert the wire adaptor in the IPC terminal block. Failure to use a wire adaptor will result in poor clamping to the conductor and dangerous access to high voltage wires/surfaces.

As a standard practice, mount wire adaptors in any terminal blocks that do not have conductors inserted. This will prevent finger access to un-used terminal block contacts.

When you insert larger conductors directly into the terminal blocks, O-rings or similar protective insulating devices should be used to ensure that it is impossible to touch bare conductors or terminal block contacts.

2.2.6.2 Three-phase delta power connections

Warning: Death, serious injury, or fire hazard could result from improper connection of this instrument. The rear of the IPC is a high voltage, high current area. Follow industry standard safety precautions at all times. Do not make electric power connections unless you are qualified to do so. Do not operate this instrument until you have received appropriate training and are familiar with this entire manual.



Follow all local safety codes, practices, and requirements. They take precedence over the instructions here.

Disconnect and lock out power before making or removing connections to your IPC.

Conductors to the source side terminal blocks of your IPC should be connected to a power source that is equipped with a disconnect switch, and with an appropriately sized current-limiting device (fuse or circuit breaker). Avoid lengthy conductors between this power source and your IPC; install your IPC as close as practical to this power source.

Always install protective earth conductors to both source- and load-side protective earth terminal blocks) with a cross section adequate to carry all available current.

All conductors connected to the IPC must be stranded, with insulation temperature rating of at least 105°C, a voltage rating equal to or greater than the voltage supplied, and of adequate cross-section for the available current.

Make sure that it is impossible for any person to touch any bare wires or terminal block contacts once the terminations have been made.

If you are using wire conductors smaller than #2AWG (34 mm^2), insert the conductor in a wire adaptor provided with your IPC, then insert the wire adaptor in the IPC terminal block. Failure to use a wire adaptor will result in poor clamping to the conductor and dangerous access to high voltage wires/surfaces.

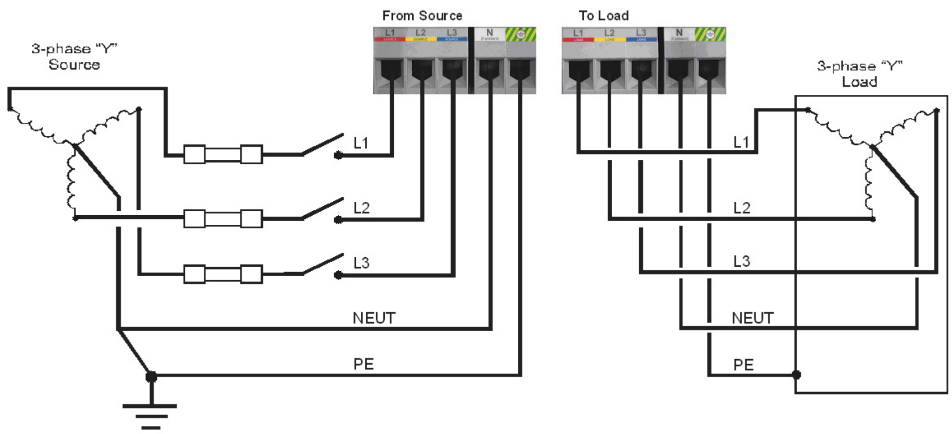
As a standard practice, mount wire adaptors in any terminal blocks that do not have conductors inserted. This will prevent finger access to potentially high voltage terminal block contacts.

The sag/swell events will be generated from phase-to-phase. If you want phase-to-neutral events, connect your IPC for wye installation (see next page). Do not use the earth conductor as a neutral.

Three-phase voltage sags/swells and interruptions will cause phase imbalance as well. Ensure that your equipment is protected against or can tolerate phase imbalance.

2.2.6.2 Three-Phase wye (star) power connections

Warning: Death, serious injury, or fire hazard could result from improper connection of this instrument. The rear of the IPC is a high voltage, high current area. Follow industry standard safety precautions at all times. Do not make electric power connections unless you are qualified to do so. Do not operate this instrument until you have received appropriate training and are familiar with this entire manual.



Follow all local safety codes, practices, and requirements. They take precedence over the instructions here.

Disconnect and lock out power before making or removing connections to your IPC.

Conductors to the source side terminal blocks of your IPC should be connected to a power source that is equipped with a disconnect switch, and with an appropriately sized current-limiting device (fuse or circuit breaker). Avoid lengthy conductors between this power source and your IPC; install your IPC as close as practical to this power source.

Always install protective earth conductors to both source- and load-side protective earth terminal blocks) with a cross section adequate to carry all available current.

All conductors connected to the IPC must be stranded, with insulation temperature rating of at least 105°C, a voltage rating equal to or greater than the voltage supplied, and of adequate cross-section for the available current.

Make sure that it is impossible for any person to touch any bare wires or terminal block contacts once the terminations have been made.

If you are using wire conductors smaller than #2AWG (34 mm^2), insert the conductor in a wire adaptor provided with your IPC, then insert the wire adaptor in the IPC terminal block. Failure to use a wire adaptor will result in poor clamping to the conductor and dangerous access to high voltage wires/surfaces.

As a standard practice, mount wire adaptors in any terminal blocks that do not have conductors inserted. This will prevent finger access to potentially high voltage terminal block contacts.

If larger conductors are connected directly into the terminal blocks, O-rings or similar protective insulating devices should be used to ensure that it is impossible to touch bare conductors or terminal block contacts.

The sag/swell events will be generated from phase-to-phase and phase to neutral.

Three-phase voltage sags/swells and interruptions will cause phase imbalance as well. Ensure that your equipment is protected against or can tolerate phase imbalance.

2.3 Types of testing

2.3.1 Choosing the type of test

Your IPC can perform several different types of electric power tests: voltage sag and swell immunity, power supply sustain time after interruptions, unbalance response, inrush current, and power consumption / harmonics tests.

Often, the most difficult part of testing is connecting your Equipment Under Test (EUT) and the IPC. Once you have connected, it makes sense to do as much testing as possible, even if you don't need all of the data immediately.

2.3.2 International standards - a brief introduction

There are two different approaches to testing your equipment: you can test your equipment to learn exactly how it performs (then perhaps improve its performance); or you can test your equipment to see if it meets or surpasses a standard.

Your IPC has several standard built-in: industry standards, such as SEMI F47, CBEMA, and ITIC; international standards such as IEC 61000-4-11; organization standards such as FAA; and military standards.

If you're not sure what standard to use for voltage sag immunity, we recommend SEMI F47 as a good general-purpose standard.

For detailed information about international standards, see the Appendix or visit www.PowerStandards.com .

2.3.3 Voltage sag (dip) / swell immunity testing

For this type of testing, you use your IPC to create sags and swells with controlled depths and durations. Use these to verify that your EUT can tolerate normal sags and swells, or, if it can't, to figure out why and fix it.

You choose the depth, duration, phase angle, and (for polyphase systems) conductor pair where the sag or swell will be applied. Then arm and fire your IPC, and see how your EUT responds.

Typically, you will connect test leads to the front panel channels on your IPC, and clip them to power supplies or other signals inside your EUT. Then when you download the waveforms from your IPC, you will be able to see exactly how your power supplies respond during sags.

One typical problem occurs after voltage sags: the EUT draws large amounts of current, and blows fuses or trips breakers. Your IPC will automatically record the current waveforms drawn by your EUT before, during, and after the sag.

2.3.4 Inrush current testing

Many electronic devices draw large amounts of current when power is first applied. Your IPC can generate 1-phase and 3-phase interruptions, and can record the current when power is re-applied.

Your IPC can also control the phase angle where power is re-applied. On three-phase systems, this phase angle can be specified for any voltage conductor pair.

You can specify the duration of the interruption. It should be long enough to allow the EUT's capacitors to discharge, motors to slow down, etc.

You may want to manually re-trigger your IPC's data acquisition system near the end of the interruption; otherwise, you will have a lot of uninteresting data that simply shows that there was no power.

Your IPC records the current waveforms; the ChannelScope II software can convert these waveforms into true RMS, the usual way of looking at inrush current.

2.3.5 Power consumption and harmonic testing

Your IPC's optional Power Flow Analysis option can be used to record power consumption and harmonic currents in a variety of ways.

It is optimized for recording power flow parameters in industrial processes: kVA, kW, kWh, kVAR, PF, THD, etc.

Your IPC can also show you real-time oscilloscope screens and spectrum analyzer screens, which can be connected to any of the voltage or current channels inside your IPC. Use these screens to track changing harmonics and verify power system waveforms.

Use your IPC's VectorScope to visually verify phase rotation, and voltage and current unbalance.

2.4 Reporting your results

We recommend using Microsoft Word for writing your reports that explain your results. Your IPC produces graphs and text that can be copied and pasted into any compatible Windows application.

Most IPC graphs can be optimized for screen or printer. And many IPC graphs include text details that show exactly when the data was recorded, on what equipment, by whom. Just use the "Event details" pull-down option.

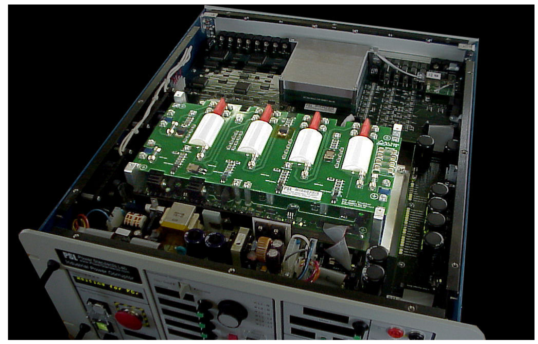
Your IPC's Power Flow Analysis option produces power consumption graphs that paste directly into SEMI E6 reports. These graphs show exactly how much energy your industrial process consumes while producing a single unit. They are ideal for optimizing the energy consumption in your process.

Your IPC is designed to support third-party certification. By filling out the Setup Test form in your IPC's software package, and carefully downloading and recording your results after each event, you can generate a complete set of files that will allow a third-party certification lab to review and certify your tests. Check with your third-party certification lab, or with Power Standards Lab at www.PowerStandards.com , to see how you can meet their requirements.

3. Technical Description of your Industrial Power Corruptor

3.1 General description

3.1.1 Theory of Operation



Your IPC is a transformer-based disturbance generator. It contains an autotransformer with multiple taps, and an extensive series of switches (electromechanical and Insulated Gate Bipolar Transistors).

Some of the switches select the correct tap on the transformer, and some of the switches connect the transformer between the appropriate input and output terminals. The IGBT's provide precision timing (to 100 microseconds) for the critical switching at the beginning and end of the event.

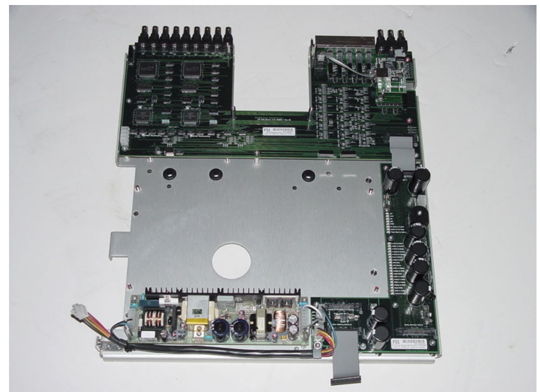
For a complete description, please see Appendix D.

3.1.2 Major modules

Your IPC has been designed in a modular format to assist in manufacturing, quality control, and service. These primary modules are as follows:

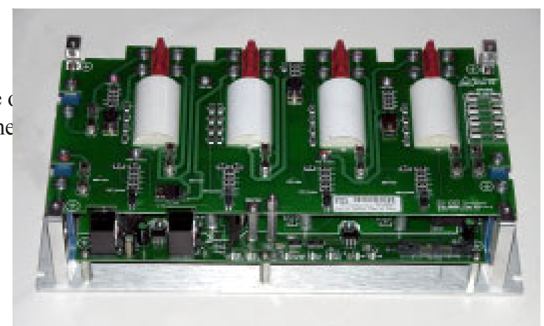
Front Panel Assembly

Consists of a Display printed circuit board (PCB) and a Control PCB mounted to the front panel with labels.



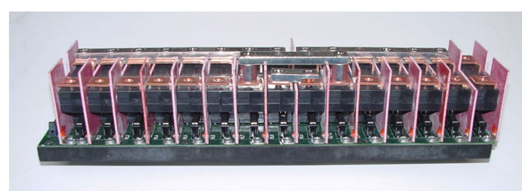
Main Chassis Assembly

The 24V power supply, the Power Supply PCB, the Data Acquisition PCB (all on the top side), and the Relay Processor PCB (on bottom side) are mounted on the main chassis plate.



The IGBT Assembly

This is a separate assembly that gets mounted to the top side c be removed and replaced should it require servicing or replaceme

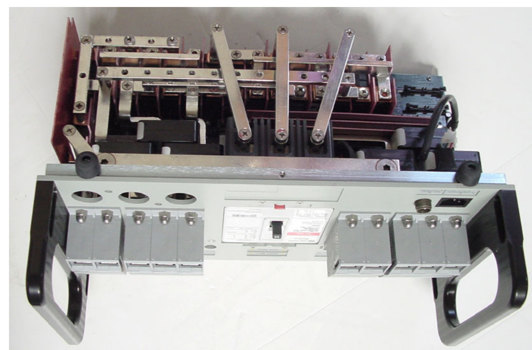


The Tap Relay Assembly

This consists of a row of 15 latching relays mounted to a PCB and supported by Delrin braces running the length of the board. The relays have interconnecting bus bars for distribution of power from the relay taps.

Transformer Assembly

The custom designed multi-tapped autotransformer is used to select the depth of a sag or swell. This transformer is mounted on its own support plate that also has an insulating termination plate. The terminations from the transformer connect to this plate and in turn receive a fuse link connection to the Tap Relay Assembly.



Rear Panel Assembly

This assembly is largely responsible for the complex distribution of power before, during, and after events. There are 16 latching relays mounted on the PCB, along with the current transformers and spring-loaded voltage test points. A multitude of convoluting bas bars wind their way around this assembly and connect to the terminal blocks. The circuit breaker and rear panel are attached to the chassis of this assembly, creating a module that can be slid in place for mounting and connections to other assemblies.

The Motor Operator Assembly (optional)

This is a customized circuit breaker motor operator assembly that can be optionally installed onto the rear panel. This can be retrofitted at any time as the rear panel comes standard with mounting locations and a three-pin circular connector. This assembly allows front panel control of the motor operator, avoiding the necessity to reach back behind the IPC every time the circuit breaker requires resetting.

3.2 Front panel features

The front panel of your IPC is the primary functional interface. It has been design to be as user friendly as possible, while allowing maximum functionality and information display.

It is separated into 3 main sections:

" The Status section where the main status display is located, along with instrument power switch/status indication, PC connection, and circuit breaker control/status indication.

" The Disturbance Settings section, where you will find the switches and displays required for selecting and starting/stopping events.

" The Meters section, where the 3 sets of meter displays, and the high and low voltage input connectors are located.

Many of the switches have a **safety cover** to prevent inadvertent operation. To operate the switch, gently raise the safety cover from the bottom.

3.2.1 Instrument power switch

The push-on, push-off Instrument Power switch on the lower left of the front panel turns your IPC on and off. This is also a backlit switch that changes from green when in the on position, to red when off. (A yellow light indicates inadequate voltage on the IPC's internal 24V power supply.)

Note that when you turn your IPC either on or off, the main circuit breaker is automatically tripped open.

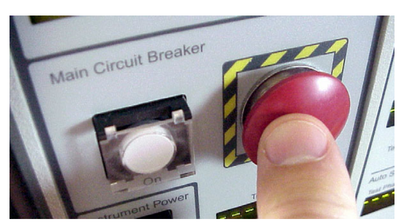
3.2.2 PC port

There is an RJ-45 jack on the lower left of the front panel of your IPC. This is used to connect to your computer. A cable and adapter are provided with your unit to enable direct connection to the DB-9 serial port on your computer. If your computer has a USB port, and no 9-pin serial connection, you will require a USB-Serial adapter. We recommend using a Belkin model F5U103.

3.2.3 Circuit breaker control

The Main Circuit Breaker emergency off button is a standard feature on all IPC's. This is the large round red button on the left side of the front panel.

Pushing this button will immediately trip the circuit breaker on the rear of your IPC. This action will also change the status light of the Circuit Breaker "ON" switch/lamp, from green to red. Tripping this circuit breaker will disconnect the "from

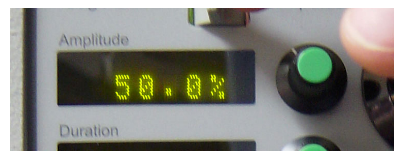


Source: terminal block connections from the "to Load" terminal block connections.

If the optional Motor Operator assembly is installed, the covered Circuit Breaker "ON" button on the front panel will function as a switch to close the circuit breaker. When this is depressed, you will hear the motor operator close the circuit breaker, and the light on the switch will turn from red to green.

3.2.4 Sag / Swell - Impulse switch

This is used to select between a sag/swell type of event, or and impulse event (impulse generation is a future option).

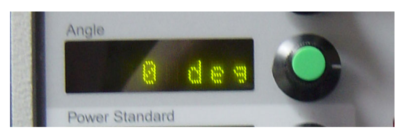


3.2.5 Amplitude dial / display

This is used to select/display the amplitude of the event, displayed as a percentage of the nominal voltage. Range: 0% to 125% of nominal.

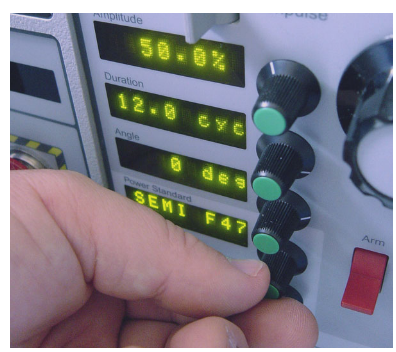
3.2.6 Duration dial / display

This is used to select/display the duration of the event. Displayed in cycles or seconds. Range: notch (200 microseconds) to 34 seconds.



3.2.7 Angle dial / display

Selects and displays phase angle for start of event. Front panel dial has 5 degree increments. Software control has 1 degree increments. The angle is measured from the positive-going zero-crossing, on the user-selected phase-to-neutral or phase-to-phase channel, on the source side.

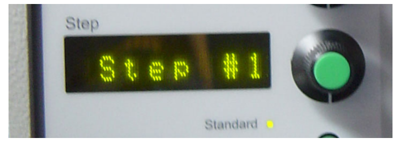


3.2.8 Power Standard dial / display

Permits selection of a standard test recipe, such as SEMI F47, ITIC, FAA 1.3.2 etc. If the standard selected has multiple steps, then each step is shown on the "Step" display below.

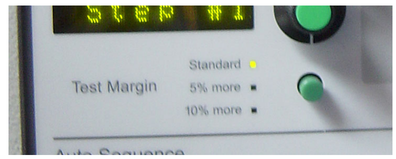
3.2.9 Step dial / display

When you select a multiple-step standard recipe on the Power Standard display, this dial permits you to choose which of the steps you want to perform. This allows you to step through a multi-step test, or go back to earlier steps if desired. If the standard selected has only one step, then Step #1 will be the only one you can select. If Auto Sequence operation is selected, then this display will automatically proceed to the next step after completion of each test.



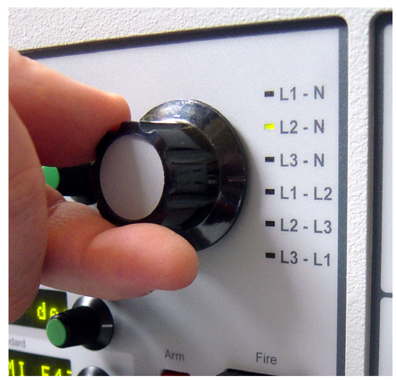
3.2.10 Test Margin button

This button is associated with the Power Standard and Step displays only. Select "Standard" for testing according to the standard you have chosen. Select "5% more" if you want to quickly test at 5% longer and 5% deeper than the standard. Select "10% more" if you want to quickly test at 10% longer and 10% deeper than the standard.



3.2.11 Phase dial / display

This allows you make a phase selection for the event. You can choose for a single-phase test (L1-N), a 3-phase delta test (L1-L2, L2-L3, L3-L1), or a 3-phase wye test (L1-L2, L2-L3, L3-L1, L1-N, L2-N, L3-N). The LEDs adjacent the phase combination will light up when selected.

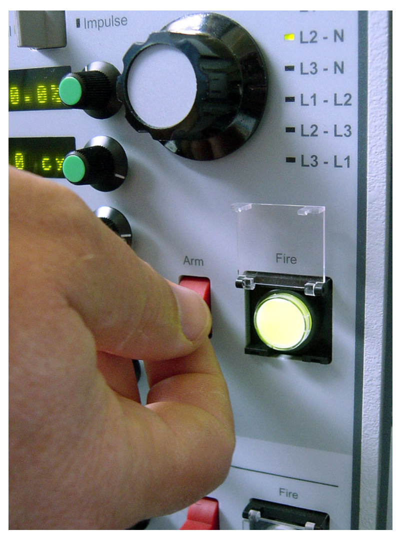


3.2.12 Arm and Fire switches - single sequence

Use the upper set of Arm and Fire switches to initiate all single sequence events (a single sequence event is one in which you to manually select each test or step).

When you toggle the Arm switch to Arm, your IPC will conduct quick internal checks, and if all is ok, allow you to press the Fire switch to start the event (if all is not ok, an error message will be displayed).

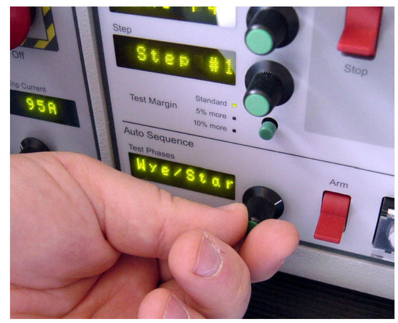
If you toggle the Arm switch to Stop after arming it, it will immediately prevent or stop the event.



3.2.13 Test Phases dial / display

This is part of the Auto Sequence function. Auto sequence automatically advances you to the next step and/or phase on a multi-step test. For safety reasons, you still have to "arm" and "fire" each individual event (using the Auto Sequence (lower) set of arm and fire switches).

Using the Test Phases dial and display, you can select a single phase, 2-phase, 3-phase delta, or 3-phase wye-star recipe. If, for example, you select a SEMI-F47 recipe on the Power Standard display, with 3-phase delta auto sequence testing (on the Test Phases display), the first test will be Step #1 on L1-L2. You then toggle the Auto Sequence arm switch and depress the fire switch next to it. After the event has ended, the Step display will advance to Step #2. When you have completed all the steps on this pair of phases, the L2-L3 phase selection LED (next to the large knob) will light up. You will continue this sequence until all the steps have been conducted on all the phases.



3.2.14 Arm / Stop and Fire switches - Auto sequence

These lower set of switches are part of the Auto Sequence function. Auto sequence automatically advances you to the next step and/or phase on a multi-step recipe. For safety reasons, you still have to "arm" and "fire" each individual event using these Arm and Fire switches.

If you toggle the Arm switch to Arm, your IPC will conduct quick internal checks, and if all is ok, allow you to press the Fire switch to start the event (if all is not ok, an error message will be displayed). If you toggle the Arm switch to Stop after arming it, it will immediately prevent or stop the event.

3.2.15 Meters

There are three sets of Meter displays on the front panel, labeled Meter, 1, Meter 2, and Meter 3.

Each set consists of the following:

" A meter selection display and dial. Use the knob to select which input you wish to assign to this display. Each of set of displays can be also be set to "off" .

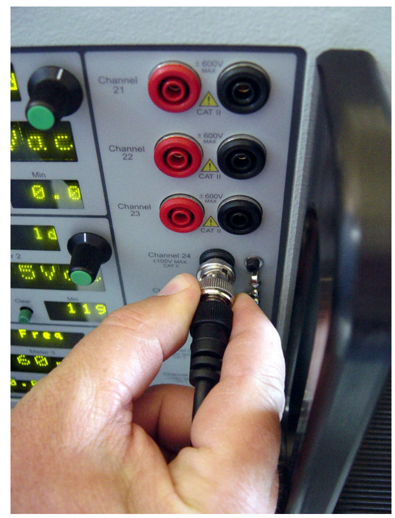
" A value display. This display shows the value of that input with its appropriate units.

" A maximum and minimum display, with an associated Clear button. This displays stores the max and min values for the channel. Although the meter displays are only updated once per second, the min/max values are updated every cycle (every 20 milliseconds at 50 Hz, 16.67 milliseconds at 60 Hz). Pushing the Clear button resets these displays.

3.2.16 High Voltage Input Channels

The pairs of banana jack connectors on the right hand side of the front panel, labeled Channel 21, Channel 22, and Channel 23 are ±600V AC or DC analog inputs. You can use these to monitor high voltage points on the equipment you are testing. Do not to exceed the rated voltage on these inputs.

3.2.17 Low Voltage Input Channels

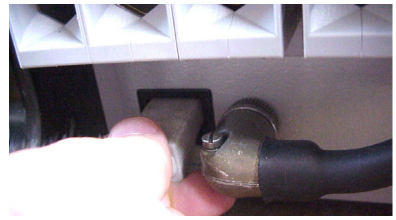


There are 6 BNC connectors on the right hand side of the front panel. These are labeled Channel 24 through Channel 29, and are analog input channels with a ±100V AC or DC maximum rating.

3.3 Rear panel connections

3.3.1 Instrument power

Find the AC inlet on the lower left of the rear panel. Connect instrument power here; see specifications for acceptable voltages and frequencies. The instrument power supply automatically adjusts to the voltage and frequency.

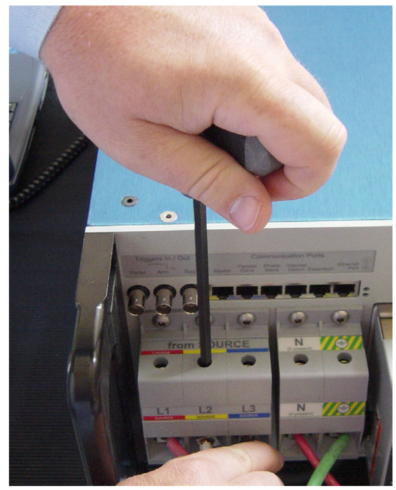


There are two sources of power in your IPC: this connector, and the power connections to the large terminal blocks on the rear panel. To remove power, remove **both** sources.

(The IPC in the photo at right has the Breaker Motor Drive option installed.)

3.3.2 Source and load connections

Your IPC has 10 large gray terminal blocks on the rear panel that have color-coded labels to help identify them. Use these terminal blocks to insert your IPC between your power source and your equipment that you want to test.



The terminal blocks are divided into 2 groups; the "from SOURCE" terminal blocks on the left side of the circuit breaker, and the "to LOAD" terminal blocks on the right side of the circuit breaker. For instructions on how to configure wiring connections to these terminal blocks, see the section in this manual on Connecting Test Power.

A 7/32-inch T-handle hex wrench is supplied with your IPC for tightening the terminal blocks.

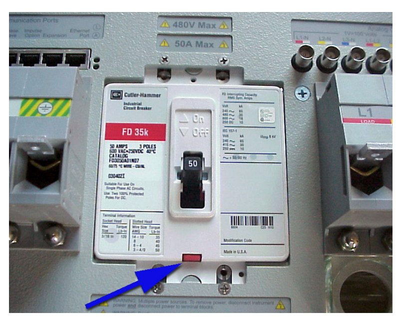
The terminal blocks accommodate stranded wire ranging from ranging in size from 35 - 90 mm^2 (#2 -4/0 AWG).

If you are using wires smaller than 35mm^2 (#2 AWG) , use the wire adapters provided with your IPC to ensure safe clamping. If a terminal block has no wires installed, then it is a good practice to install the wire adapters in these locations also. A 3/16-inch T-handle hex wrench is supplied with your IPC for tightening the wire adapters.

3.3.3 Main circuit breaker

The main circuit breaker disconnects the "from SOURCE" terminal block from the "to LOAD" terminal blocks. This circuit breaker does <u>not</u> interrupt the IPC’s instrument power.

If an optional motor operator is not installed then the operating handle and position indicator are exposed.



The circuit breakers' voltage and current rating match the internal design of your IPC. Your IPC’s software and firmware continually monitor the state of the circuit breaker, and trip it when the IPC is turned off, or when an error condition is observed.

The blue arrow in the photo at right points to the manual trip test button.

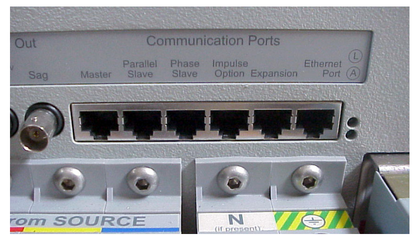
3.3.4 Triggers in/out BNC connectors (panic, arm, and sag)

On the upper left corner of the rear panel there are three BNC connectors. These are 0V min, 24V max signals. Do not connect other voltages to these connectors. The shield side of these BNC connectors in connected to the chassis.

You can use the signals on the ARM and TRIGGER BNC connectors to trigger external data acquisition - the ARM signal will go low approximately 2 cycles before the event begins, and the TRIGGER signal will go low exactly as the event begins.

You can use the PANIC BNC to provide a remote trip switch for the main circuit breaker. Simply shorting across the PANIC BNC will assert the internal Panic signal, which will shunt-trip the breaker.

(These BNC connectors also play a role in a future option that allows multiple IPC's to work together.)



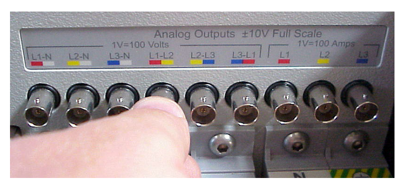
3.3.5 RJ-45 rear panel communications ports

To the right of the BNC connectors on the upper left of the rear panel, there is a row of 6 RJ-45 connectors. These connectors are all reserved for future expansion capabilities.

3.3.6 Analog outputs

On the upper right area of the rear panel, find a row of 9 BNC connectors.

These are all ±10-volt scaled analog outputs of the internal voltage and current readings, on the load side of the IPC. These signals are digitized and stored by your IPCs' data acquisition system, but having them available as outputs offers a convenient means of reading the data on an oscilloscope, chart recorder, etc.



The signals include both phase-to-neutral and phase-to-phase voltages, scaled at 1 volt out = 100 volts in . The three current outputs are scaled at 1 volt out = 100 amps in.

The shield side of these BNC connectors in connected to chassis, and there is a 5 kiloHertz low-pass filter on the signals. The source impedance of the signals is approximately 1k ohm.

3.3.7 Motor drive for circuit breaker (optional)

This convenient option lets you close the circuit breaker from the front of the IPC, avoiding the requirement to reach over to the back of the IPC (near high voltage connections) in order to manually turn the breaker on.

The 3-pin circular connector next to the Instrument Power AC inlet is the electrical connection point for this assembly. Retrofitting this assembly is as simple as aligning the circuit breaker lever and motor operator guide (important; see instructions below), attaching the motor operator to the rear panel using the 4 screws provided, and plug its cable into the circular connector on the rear panel.

The motor operator assembly is locked in operating position using the screw and cap nut on the rear tabs. If access the circuit breaker lever is required for any reason, the motor operator does not need to be removed from the rear panel. Removing the screw and cap nut, and pull down on the outer tab. The motor operator will hinge open. However, care must be taken when re-closing this assembly, as it is very likely that the circuit breaker lever and motor operator guide may not be aligned. If the motor operator is closed in the wrong alignment, it may burn out the internal motor.

The correct procedure in mounting/re-closing the motor operator assembly is as follows:

1. Manually (or using the front panel Circuit Breaker Off button if the IPC is running) move the circuit breaker lever fully to the OFF position.

2. Using a flat head screwdriver, turn the slotted shaft of the motor operator until the arrow on the white lever guide aligns with the OFF arrow on the back plate.

3. Attach the motor operator to the rear panel using the 4 #8-32 x 3/8" screws provided (or close and lock in place the hinged motor operator assembly if it is already attached).

3.3.7 Impulse generator connectors (optional)

The high-frequency, high-energy impulse generator is a future option.

3.5 Software

3.5.1 Brief description

Your IPC communicates with a Windows® computer. You must install the IPC software on your computer before you can operate your IPC.

Your IPC comes with three programs, which can be found on the IPC CD-ROM.

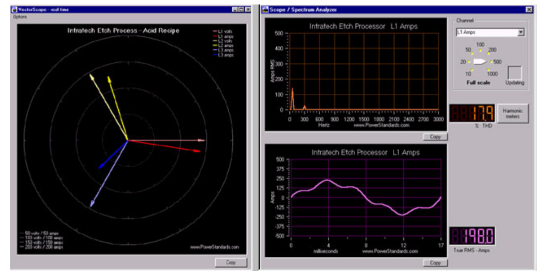
The **IPC Software** is a program that operates your IPC. It lets you set up events, helps you describe and document your tests, and downloads waveform files that your IPC recorded during tests.

All files generated by the IPC Software are in an industry-standard .CSV format. You can examine them with any text editor, and graph them with any spread sheet program such as Microsoft Works or Microsoft Excel. However, these general purpose programs are not optimized for looking at power waveforms, so PSL provides two additional programs.

The **ChannelScope** is a program that lets you graph recorded waveforms. You can zoom in and out, examine the values of individual data points, synchronize across channels, and even convert waveforms to RMS values. You can copy and paste graphs to any document, and instantly switch between printer-friendly graphs and screen-friendly graphs.

The **FlowScope** is a program that lets you graph recorded power flow parameters, such as kWh, kVARs, THD, power factor, and much more. It automatically color-codes the graphs to show you what parts of your process consume the most energy. Like the ChannelScope, you can copy and paste graphs to any document, and instantly switch between printer-friendly graphs and screen-friendly graphs. (To generate data for the FlowScope program, you need to install the Power Flow Analysis option on your IPC.)

Both the ChannelScope and the FlowScope come with sample data files.



The Power Flow Analysis option adds vector scopes, spectrum analyzers, harmonics meters, and every imaginable kind of power flow meter - kWh, power factor, kVAR, THD, and much more.

3.5.2 System Requirements

The IPC software has been tested with the following versions of Windows:

Windows 95

Windows 98

Windows 2000

Windows XP Home

Windows XP Pro

Your computer must have a serial port available. (Note that some programs, such as hot sync programs for hand-held computers, take over the serial port even when they are not active. These serial ports are not available unless you de-activate that program.)

If your computer does not have a serial port, a USB-to-serial adaptor may be used, but it must support on-the-fly changes in baud rate. Certain USB-to-serial adaptor chip sets were manufactured in 2002 and 2003 with a bug that prevents these changes. If a USB-to-serial adaptor is needed, we recommend *Belkin USB Serial Adapter F5U103*.

We recommend a fast Pentium 3, or higher, processor. If your processor is too slow, the IPC software will give you a warning message. The optional Power Flow Analysis software requires more processing power than the rest of the programs.

PSL can provide a free software tool for checking your serial ports. Contact us at www.PowerStandards.com .

3.5.3 Installation

1. Insert your IPC CD-ROM. It should automatically start. (If it does not start, browse your CD-ROM and double-click on the "CDStart" application.)

2. Click on the "Install IPC Software" link. You will probably be asked if you want to download the program, or run it or open it in its existing location. We recommend running it from its existing location. (Some browsers, such as Mozilla, may require you to download the software

   and save it. If you take this approach, browse to the location where you saved it and double-click on the "Setup" application.)

3. We strongly recommend that you accept all of the default installation parameters.

4. Repeat the installation process for the other two programs on the CD-ROM.

5. In your Start / Programs menu, you will find a new folder called "Power Standards Lab". All three programs will be inside this folder.

6. If you need to remove one or more of the programs, use your Control Panel's "Add/Remove Programs" feature.

We strongly recommend that you accept all of the default values during setup.

Install all three programs on the CD-ROM. They will appear in your "Program – Start" menu in a folder called "Power Standards Lab".

3.5.4 Planning your test

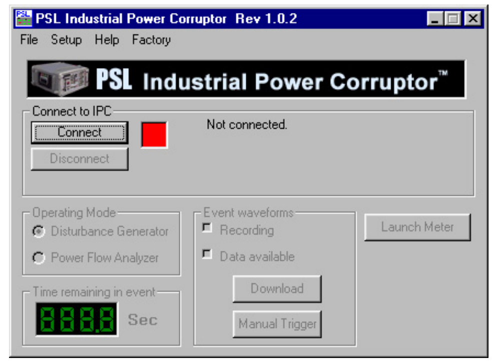
3.5.4.1 Starting the IPC software

To operate, your IPC requires a connection to a Windows™ PC running the IPC software package.

The IPC software package manages the IPC functions, in cooperation with the five processors inside your IPC. The internal processors are responsible for precision timing, data acquisition, and all power controls. The IPC software package on your computer is responsible for parts of the user interface, general timing, making decisions, and data recording.

Look in your Program/Start menu for a folder called "Power Standards Lab". Double click on the IPC Software package.

When it starts, click on the "Connect" button.



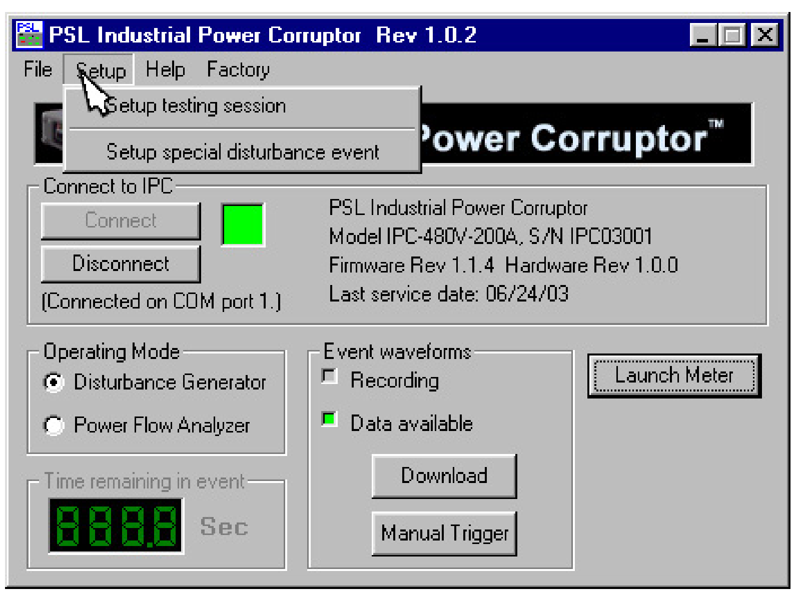
3.5.4.2 If you can't connect

1. Check that your IPC is showing "Waiting for PC…" in its status display.

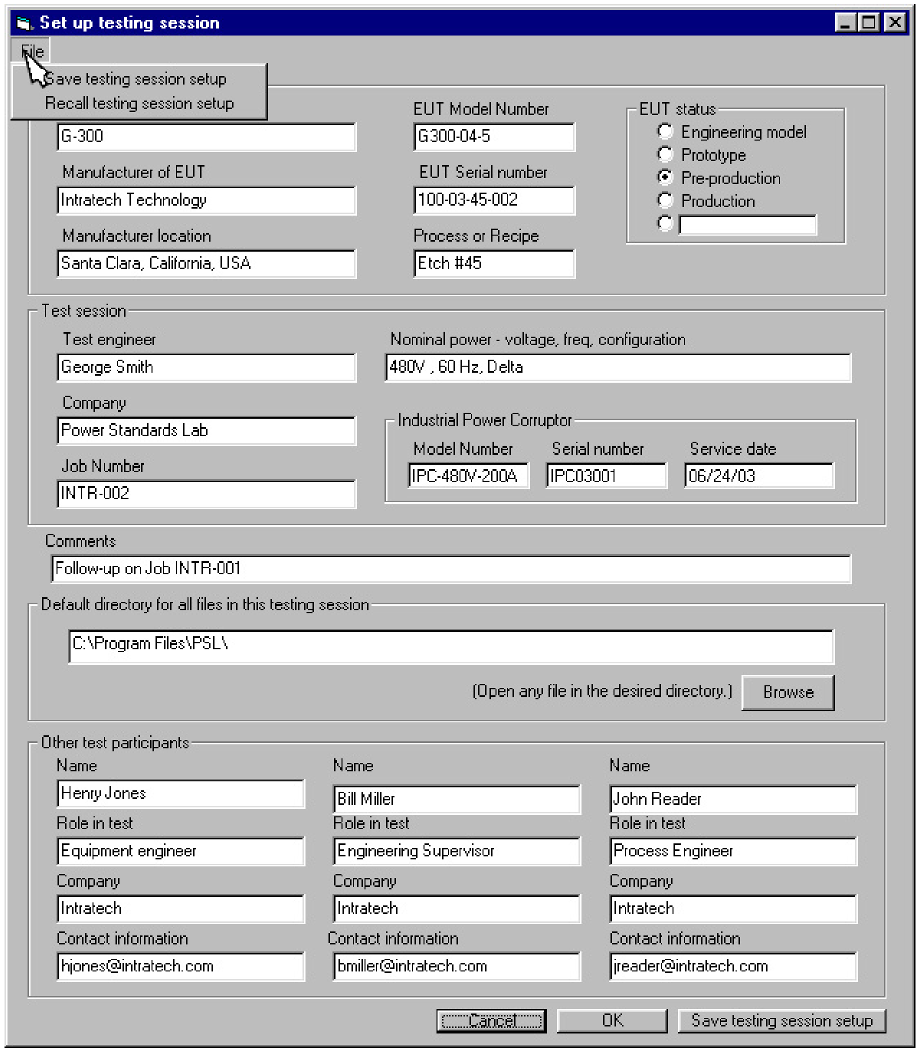
2. Check that the coms cable is plugged into the correct connector on the front of your IPC.

3. Check that the coms cable is plugged into the DB9 connector, and that the DB9 connector is plugged into an available serial port on your computer.

4. Verify that the COM port is actually available. There may be another program that has seized that port, such as a hot-sync program for a hand-held computer. You can use the "COM Port Diagnostics" program from PSL to check your com ports.



Properly connected to your IPC, the software is ready to help you set up your testing session.



3.5.4.3 Setting up your testing session

Use the "Setup" pull-down menu to record all the information about your testing session.

You can record information about the "Equipment Under Test", the engineers who are involved in the testing, the nominal voltages and frequencies, and more. You can also set up a default directory, or folder, to store all the data from this test session.

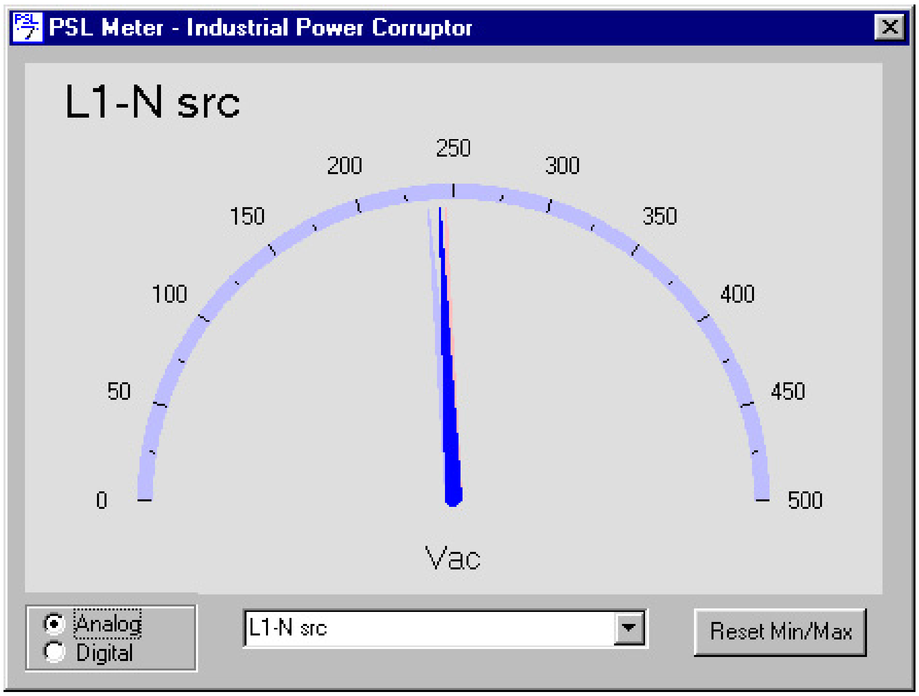
After you complete the setup, we recommend that you save it in a file. Use the "File" pull down menu on the setup form.

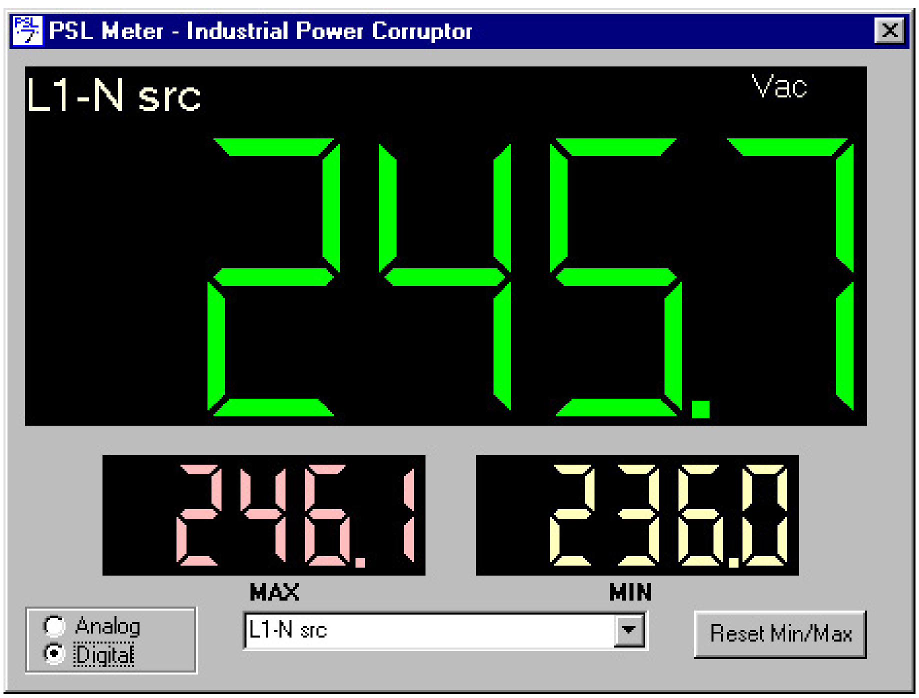
For an example of how to set up your testing session, use the "File" menu to recall the "SampleSetUp".

The data that you enter on the Setup form will be stored with any waveforms that you record. For example, see "Event Details" in the ChannelScope section.

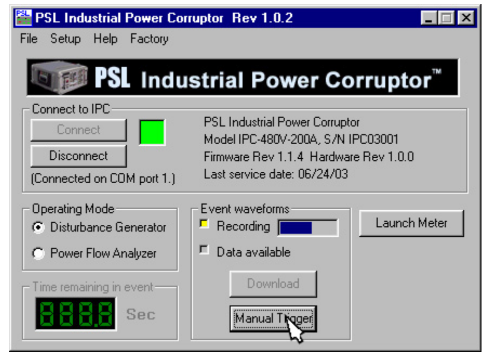
3.5.5 On-screen meter

Click on the "Launch meter" button. You can choose an analog or a digital meter, and you can connect it to any of your IPC's data acquisition channels. For more information about how these channels function, see the "Meters" section of the Front Panel description.





3.5.6 Triggering, selecting channels, and downloading



Your IPC contains a 35-channel digital oscilloscope, capable of recording several seconds of high-speed data on every channel.

This oscilloscope is automatically triggered whenever you use your IPC to generate a disturbance event, but you can also manually trigger it with the "Manual trigger" button on the opening screen. Try clicking on the "Manual trigger" button.

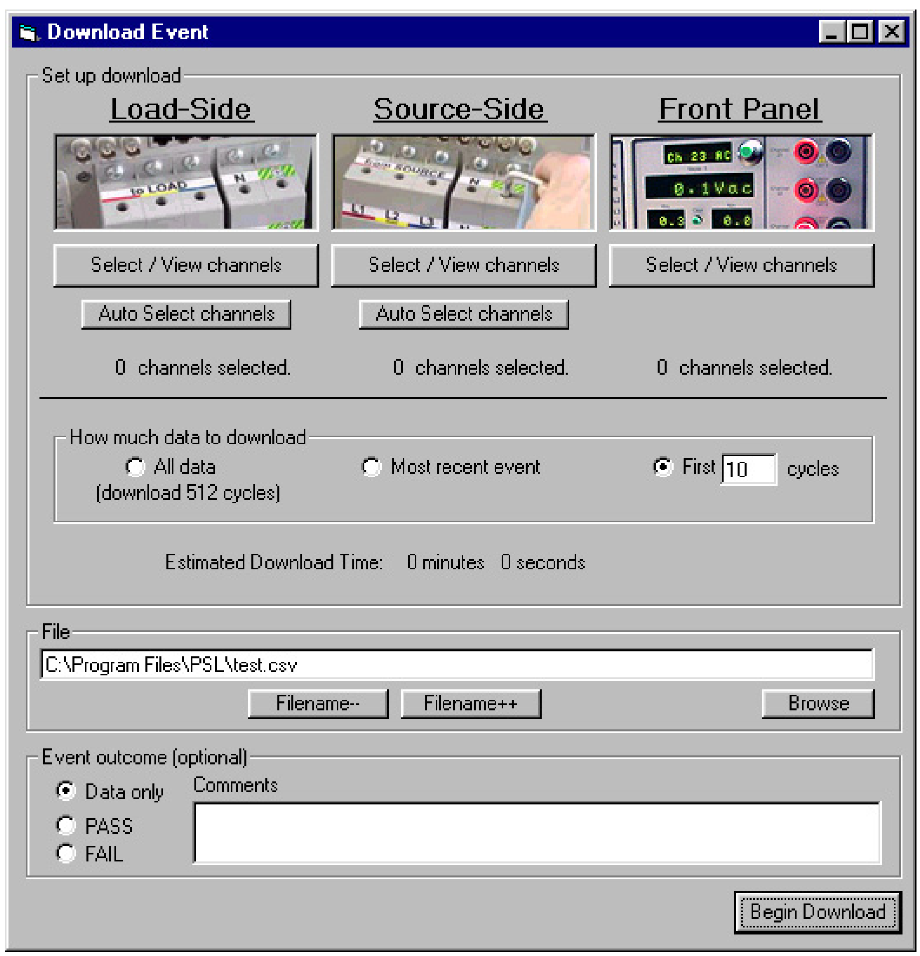
For very long events, such as 3-phase interruptions designed to examine start-up current, you may want to manually trigger the scope near the end of the event, so you can capture all of the data at the end.

Your IPC's digital oscilloscope stores the waveforms in RAM. If you want to save the waveforms, or look at them, you must download them to your PC.

Click on the "Download" button on the opening screen. You can choose which channels to download, and you can choose how much data to download. The software will automatically calculate how long the download will take.

You can also choose where to store the downloaded waveforms on your computer. You will use the ChannelScope software package to view the waveforms.

Use the "Select Front Panel Channels" button both to choose

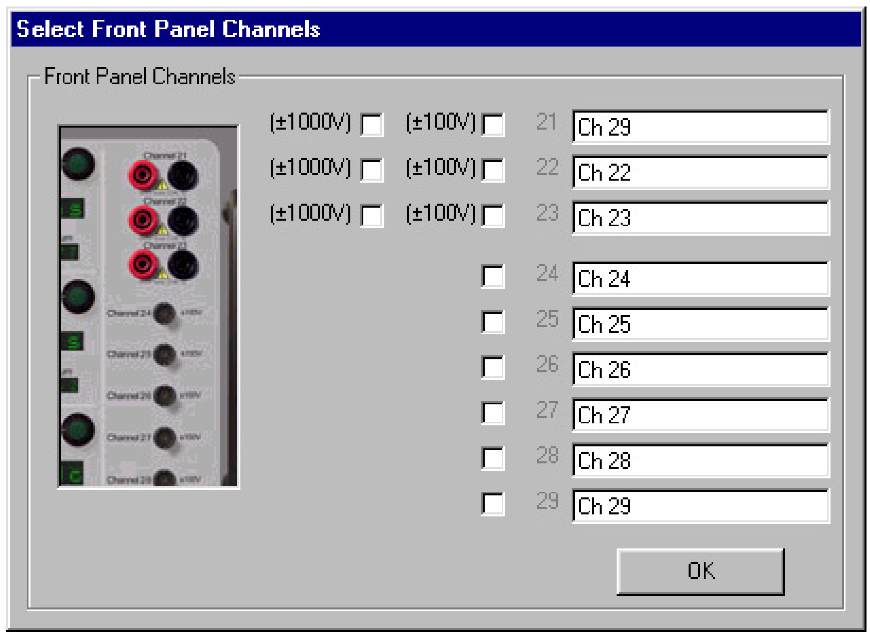


which channels to download, and to re-name the channels. It is helpful to keep the channel names to 5 characters or less, for example "+24V". These new names will appear on your IPC's front panel meters, the on-screen meter, and on the ChannelScope waveforms, making it much easier to keep track of what each channel is used for.

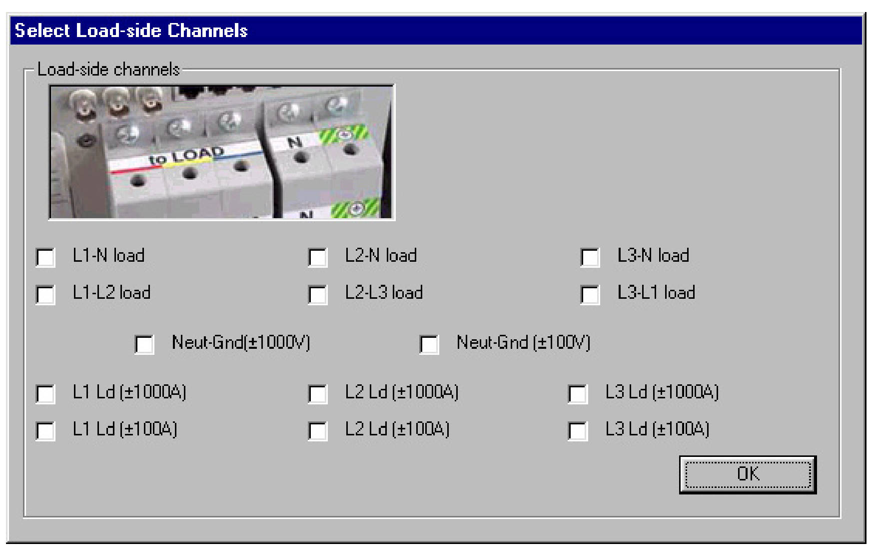
To simplify file naming in a long series of tests, you can use the "File Name ++" and "File Name -" buttons to increment and decrement the file names.

Fill in the "Event outcome" section if it is useful. The information you enter here will be recorded in the file, along with the waveforms. See "Event Details" in the ChannelScope section.

If you find that you have downloaded the wrong channels, or not enough data, you can download again - the oscilloscope data in your IPC is not erased until another event is triggered (or power is turned off).

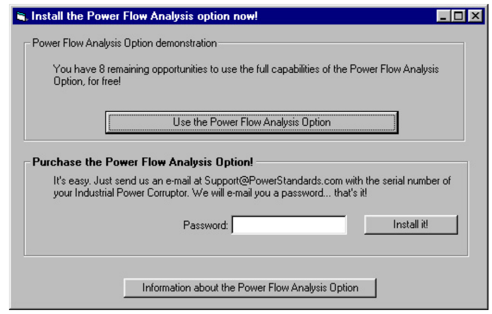


You can re-name the front panel channels - use this screen. It makes sense to limit the names to 5 characters or shorter.



On the load side, you can choose 100-amp or 1000-amp recordings - both are available, and if you're not sure which one you need, check both boxes.

3.5.7 Power flow analysis option

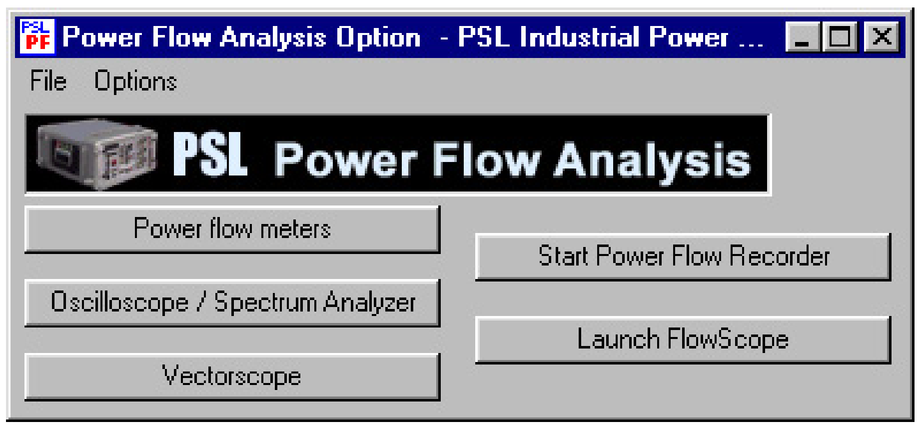


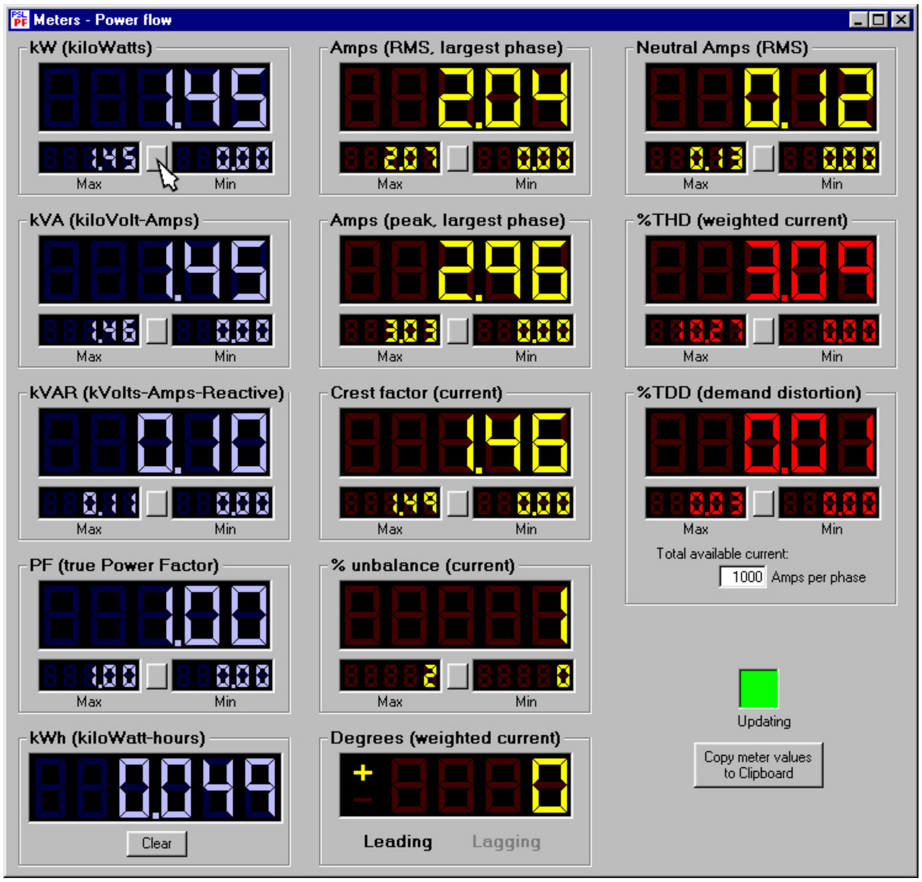
By default, your IPC operates as a disturbance generator. But by clicking the "Power Flow Analyzer" button on the opening screen, your IPC can become a sophisticated, easy-to-use power meter.

Power flow analysis is an option. Every IPC comes with a version of this option that is limited to a certain number of uses. When you choose to purchase this option, you will receive a password. Once you install the password, this option will be permanently installed in your IPC, and you will never need to install it again.

The power flow analysis option analyzes the power flow on the Load side of the IPC. In other words, it analyzes the Equipment Under Test.

The Power Flow Analysis option requires significant computer power. If your computer's response slows down, you may want to switch back to Disturbance Mode while you work with other programs, such as word processors and spreadsheets. Or you may want to find a faster computer.





3.5.7.1 Power flow meters

The power flow meters show the present value, as well as the minimum and maximum value, for each parameter. Click on the small button between the min/max meters to reset the min/max values.

All of the meters are calculated from phase-locked, 128-sample-per-cycle data. The meters are updated once per second - if your computer is unable to work quickly enough, a warning message will appear, and you will need to find a more powerful computer. The phase-locking takes place on the L1-N voltage channel (or the L1-PE channel for power systems that do not have a neutral).

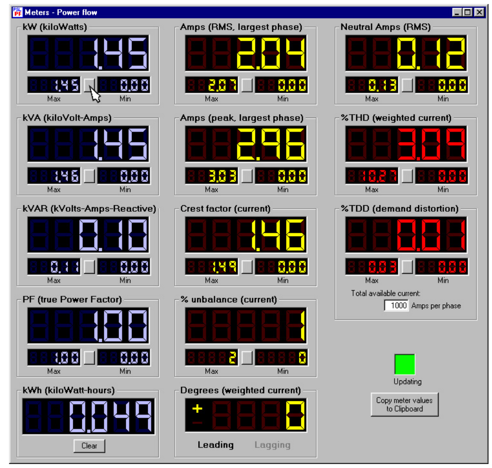
kiloWatt meter - The true power flowing into the Equipment Under Test, regardless of the number of phases, unbalance, power factor, etc.

kiloVoltAmperes - The product of the true RMS voltage and true RMS current on each phase.

kiloVoltAmperesReactive - The geometric difference between the kW meter and the kVA meter. This form of kVAR meter includes harmonic currents (and harmonic voltages, too, if present).

Power Factor - This is the true power factor, not the cosine of the angle between voltage and current. It is the ratio of kW to kVA. For displacement power factor, take the cosine of the Degrees meter.

kiloWattHours - The integration of the kW meter over time. You



can reset this meter to zero, at any time, by pressing its "Clear" button. Useful for measuring the energy consumption of your industrial process.

Amps (RMS) - The true RMS current on the phase conductor with the largest current.

Amps (peak) - the absolute value of the peak current on the phase conductor with the largest RMS current. For a sinusoidal current, this meter reads approximately 1.4 times the RMS value.

Crest factor - the ratio of Amps (peak) to Amps (RMS). Useful for sizing transformer cores, and useful as a quick measure of current harmonics - any reading that deviates from 1.4 indicates harmonic currents are present.

Percent unbalance - On three-phase systems, the percent unbalance in the three-phase current. This meter has no meaning for single-phase and split-phase systems. There are many different unbalance formulas in use; this meter calculates the unbalance as the difference between the largest RMS phase and the smallest RMS phase, divided by the largest RMS phase.

Degrees - weighted current - The angle between the fundamental current and the fundamental voltage. On polyphase systems, this angle is weighted by the RMS current on each phase. Leading and lagging are indicated, both by sign and explicitly.

Neutral amps (RMS) - the true RMS of the instantaneous summed current in the three phase conductors.

Percent THD - The ratio of harmonic current to either fundamental current or RMS current, depending on the option you selected on the Power Flow drop-down menu. This meter is weighted based on the RMS current on each phase. Total Harmonic Distortion.

Percent TDD - Similar to THD, but the ratio is to the available current, which you enter in the box below the meter. Total Demand Distortion.

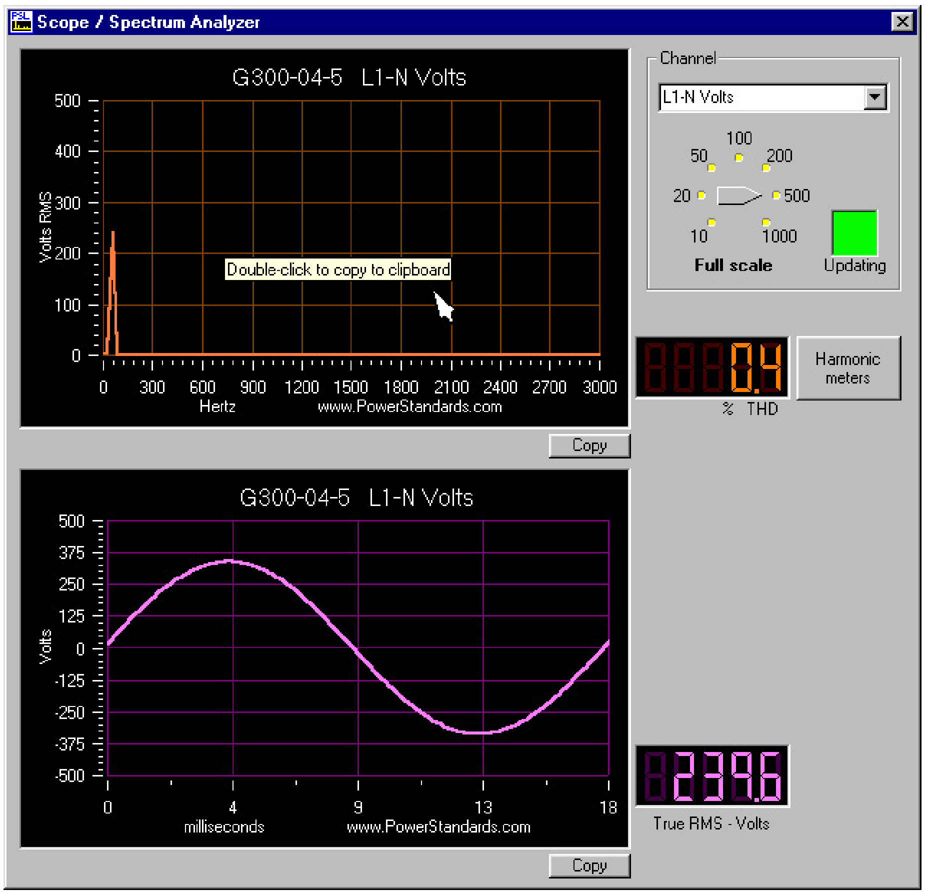
You can copy the present meter values to your computer's clipboard. They will be copied as standard text, so you can paste them into any document.

3.5.7.2 Oscilloscope / spectrum analyzer

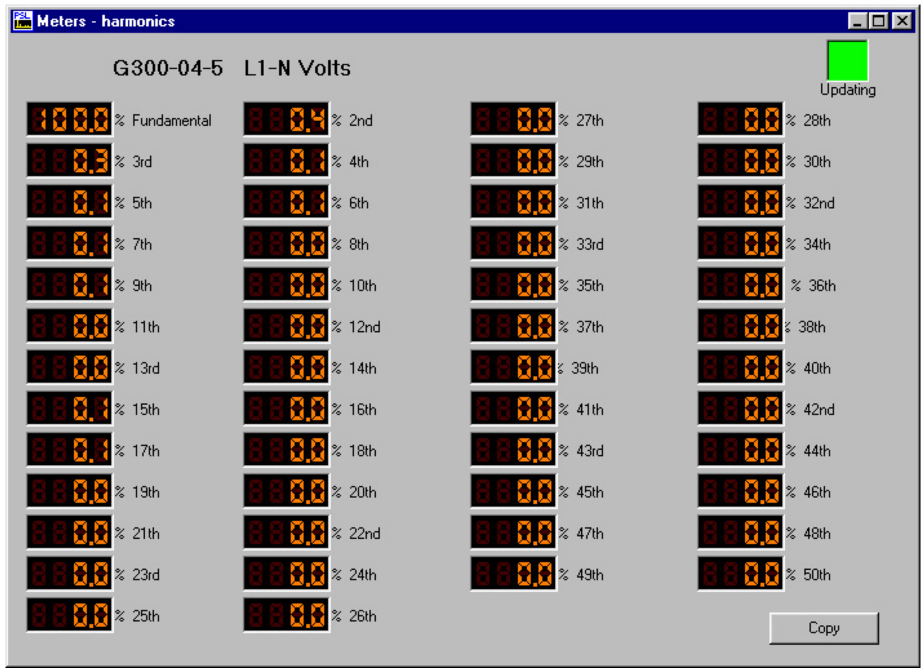
Analyzing power system waveforms is easy. Just click the "Oscilloscope / Spectrum analyzer" button on the Power Flow Analysis screen. Use the box at the upper right to choose the channel, and to set the full-scale reading for both the oscilloscope and the spectrum analyzer.

Double-click on the screen, or click the "Copy" button, to place the graph on your computer's clipboard. You can paste it into any compatible program, such as Microsoft Word.

The title on the graphs comes from the information you provided in the Setup form.



To see individual harmonics, click on the "Harmonics meters" button. The "copy" button places the present value in all of the harmonic meters onto your computer's clipboard, formatted as simple text.

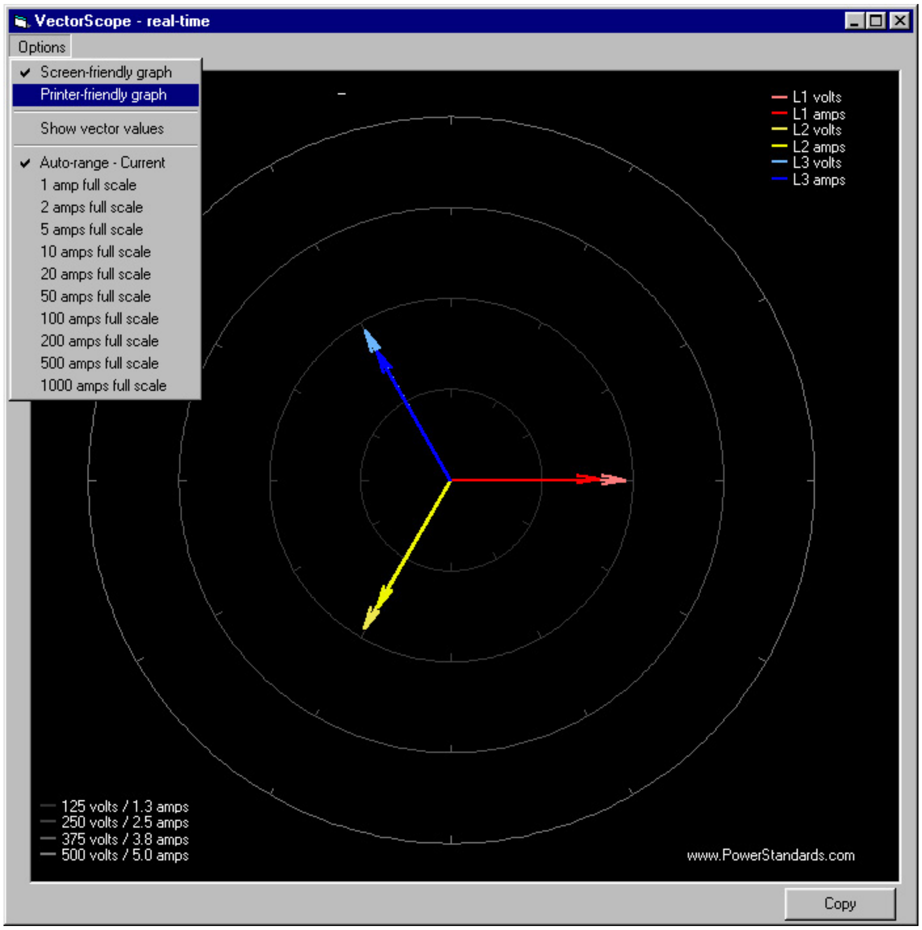


3.5.7.4 Vector scope

Your IPC's Power Flow Analysis option includes a sophisticated, real-time vector scope. You can use this tool to verify phase rotation, and to check the angles and balance of voltages and currents.

The VectorScope extracts and analyzes the fundamental voltages and currents, and their relative angles; harmonic voltages and currents have no meaning on a display like this.

By choosing the appropriate options, you can adjust the graph colors to minimize printer ink consumption, display the amplitude and angle values with each vector, and set a fixed current full scale (useful if the current is rapidly changing, and you don't want the vector full-scale to change with it).



3.5.7.5 Power flow recorder

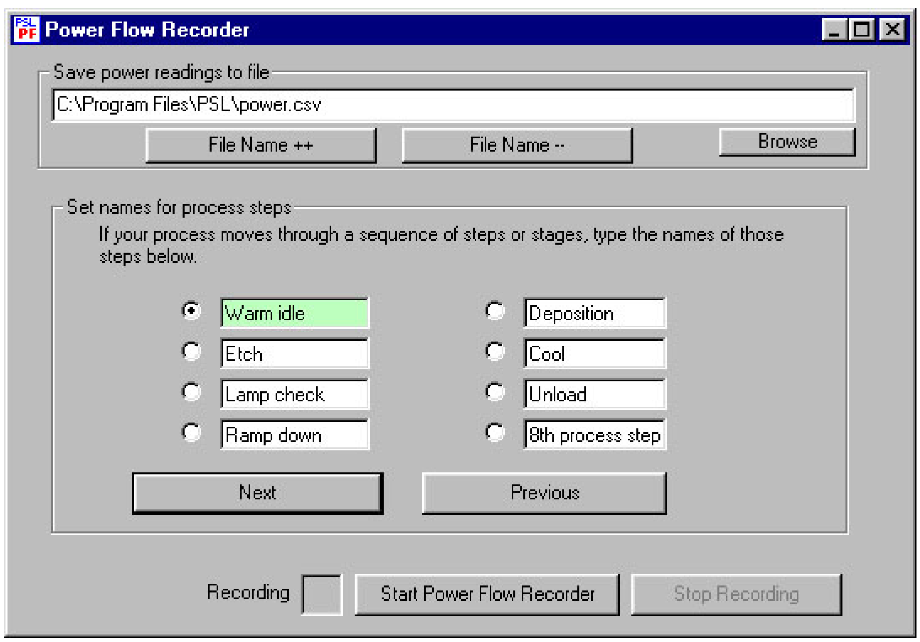
The Power Flow Recorder is probably the most powerful and useful feature of your IPC's Power Flow Analysis option. You can record all of the power flow parameters, in real time, to your computer's disk. Then use the FlowScope software to graph and display the results.

The Power Flow Recorder is designed with industrial processes in mind. Different steps in your process take different amounts of power, and have different power characteristics. Start by entering the names of up to 8 different steps.

When you start the Power Flow Recorder, it will record all of the power parameters, once per second, in the disk file you selected. Along with the power parameters, it will record which process state is active. So you should watch your process, and click on each new process state as it begins. There's no problem with going back and forth between steps - just click on the step that is in process now.

The Power Flow Recorder will record kW, kVA, true PF, kWh, Amps RMS, Amps Peak, Crest Factor, Unbalance, THD, and TDD.

When your process concludes, stop the Power Flow Recorder. Use the FlowScope software to graph the results, which can be copied and pasted into your report.



3.5.8 ChannelScope II

The ChannelScope II software lets you work with recorded power waveforms.

You can graph them, zoom in and out, synchronize across channels, pick out values on waveforms, convert complex waveforms to RMS values, and more.

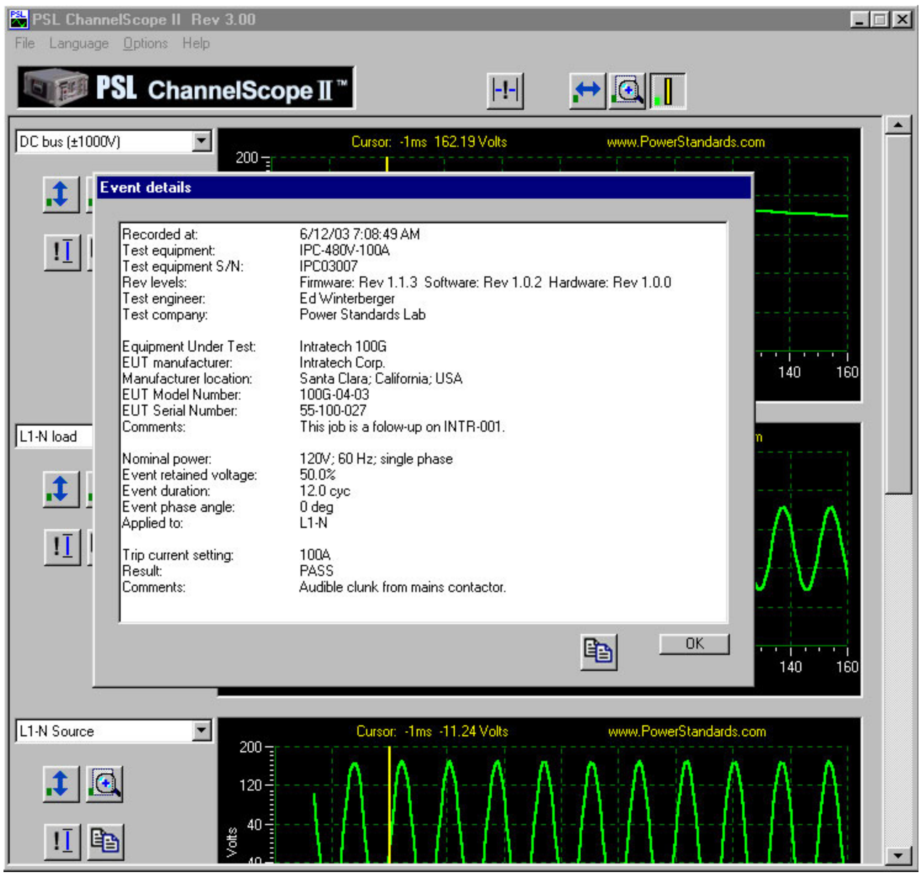
Use your IPC's built-in 35-channel digital oscilloscope to record voltage and current waveforms. It automatically triggers whenever you create a power disturbance, or you can manually trigger it using the Manual Trigger button in your IPC Software. Use your IPC software to download the waveforms to a file.

All of the data is stored in industry-standard CSV files, which can be opened by any spreadsheet program. However, we recommend using the ChannelScope II software because it is optimized for presenting this type of data.

Start the ChannelScope II software, then use the File menu to open the sample data file.

Under the Options menu, select "Event Details". You will see the date and time the event was recorded, all of the information about the test equipment and the Equipment Under Test, and - if you entered the optional information during the download - comments about what happened during the test. (Some of these event details are generated automatically, some of them come from what you enter in the Test Setup form, and some of them come from comments you entered before downloading the data.)

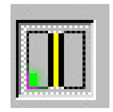
You can copy the event details to your computer's clipboard by clicking on the Copy icon button below the event details text.



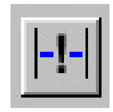
Now look at the graphs. You can choose which values you want to display with the drop-down lists to the left of each graph.

Note that the list includes both the waveforms, and the RMS values of the waveforms. This can be very useful for analyzing maximum RMS current after voltage dips, looking for peak breaker currents, etc. (These are the sliding true-RMS values, calculated over one cycle and advancing one sample per sample interval, so the initial cycle of data may not be representative.)

You can zoom and scroll left and right, using the buttons at the top of the ChannelScope II. All of the graphs move left and right together. To scroll or zoom, click on one of the buttons at the top, then place the cursor in a graph, hold the left mouse button down, and slide the cursor left or right.



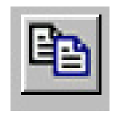
Then align all of the graphs by clicking on the yellow cursor button.



To restore the default left-right values, click on the button with the exclamation mark.

You can drag the yellow cursor left or right on each graph (the other cursors will track the changes you make). The text at the top of the graph will show you the position of the cursor, and the value of the graph at that time.

You can zoom and scroll each individual graph vertically, too. Just click on the button to the left of the graph, then place the cursor in the graph, hold the left mouse button down, and slide the cursor up or down.



Click on the clipboard icon button, to the left of the graph, to copy the graph to your computer's clipboard. You can then paste it into any compatible Windows program, such as Microsoft Word. (You may want to use the Options drop-down menu to choose "Printer-friendly graphs" if you want to conserve printer ink.)

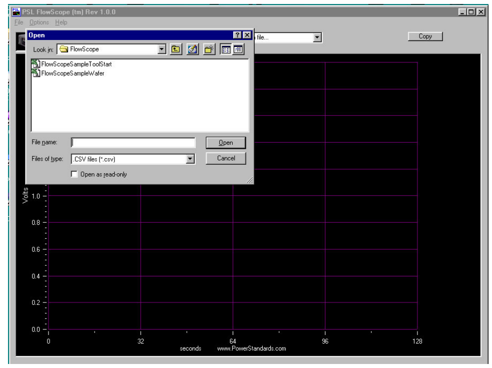
3.5.9 FlowScope

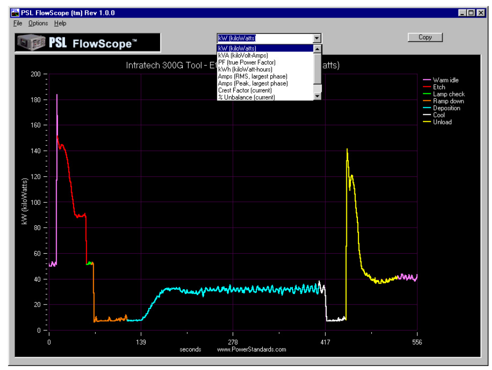
The FlowScope software lets you analyze and graph power flow parameters. It is optimized for analyzing industrial processes.

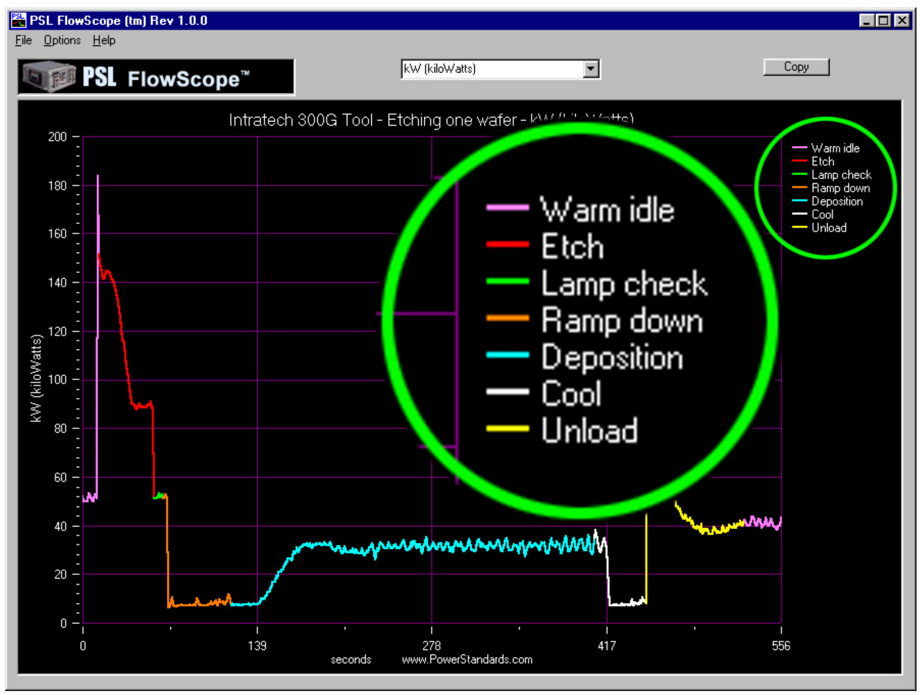
Use your IPC's Power Flow Recorder (part of the Power Flow Analysis option) to record a data file for the FlowScope software. Two sample data files are provided with the program. All of the data is stored in industry-standard CSV files, which can be opened by any spreadsheet program. However, we recommend using the FlowScope software because it is optimized for presenting this type of data.

Start the FlowScope software, then use its File menu to open a file. Use the Options menu to select the type of graph you would like to display. Double-click on the graph (or click the Copy button) to place the graph on your computer's clipboard.

Use the drop-down box, at the top center, to choose the power flow parameter you want to display.







Appendix A - Status messages

Armed.
The IPC is armed and ready to perform the next event. Press one of the “Fire” buttons to trigger the event.

Bad snubber fuse
The user has attempted to start and event, but the IPC has detected that one or more of the fuses on the IGBT snubber board is open. This board is equipped with several spare fuses. Following all safety precautions, replace the fuse. (These fuses may operate if there are large voltage transients on the AC line, which can be caused by very large switching inductive loads.)

Brkr is off.
The main circuit breaker, on the rear of the IPC, is off, so the IPC is unable to begin the next event. Turn the breaker on and try again.

Connected to PC.
The IPC has successfully established communication with a Windows computer running the IPC software package.

Doing event NN.N
The IPC is doing an event – a swell, a sag, an interruption, etc. Numbers are shown for longer events – they show the approximate number of seconds remaining in the event.

Error(NNNN)01-NN
An internal fault has occurred in the IPC. The first 4 digits show the specific fault, and the last 2 digits show the processor that caused the fault. Check the board-to-board cables inside the IPC. Cycle the IPC’s power. If the problem occurs again, contact the factory.

IGBT fault
One of the four main IGBT’s (insulated gate bipolar transistors) has indicated an internal fault. This can be a temporary fault, typically caused by currents in excess of 800 amps. Adjust the load or source, and try again. If the IGBT fault is permanent, then the IGBT has been damaged, and the IGBT module must be exchanged. Contact the factory.

Internal fault N
N=2, 3, 4, 5, or 6
The Control Processor is unable to communicate with one of the other internal processors in the IPC. The Panic signal is asserted. Cycle the IPC’s power. If the problem occurs again, contact the factory.

Invalid phase.
You have attempted to initiate an event, but the phase selection doesn’t make sense. For example, you may have set the Test Phases to “Delta”, but have the Phase Selector knob set for “L1-N” – there is no neutral in a Delta system, so the IPC is not sure what you want to do. Check your selection on the Test Phases display against your selection on the Phase Selector knob.

No motor drive.
The user has pressed the main circuit breaker “On” switch on the front panel, but the motor-operated circuit breaker option is not installed. Turn the breaker on manually.

Overheated relay
The IPC has terminated an event because one of its bypass relays has reached a programmed temperature limit. This is usually caused by rapidly repeating several long, very high current events. Allow the relay to cool. You can monitor its temperature on the front panel meters.

Ready.
The IPC is ready to begin the next event.

Ready. (bad freq)
The IPC is ready to perform an event, but the zero-crossings on the channel selected by the Phase Selector knob show a frequency that is outside the acceptable range for the IPC. Use the IPC’s frequency meter to diagnose the problem, and correct it.

Ready. (no AC)
The IPC is ready to perform an event, but it cannot find any zero-crossings on the channel selected by the Phase Selector knob. Apply power to the IPC, or choose the correct phase.

Starting up… N
The IPC is proceeding through its normal start-up process, which includes booting up all processors, coordinating their operation, etc. Wait for the process to conclude.

Trip:Brkr motor
The IPC tripped its main circuit breaker because the motor drive option is installed, but it failed to operate the circuit breaker in the time allowed by the IPC. This may indicate that the motor drive option was not aligned correctly when it was installed, or it may indicate that the motor drive option is plugged in electrically but is not installed mechanically, or it may indicate a defective motor drive option. Service is required. However, to avoid testing delays, the motor drive option may be removed and the circuit breaker may be operated by hand.

Trip:ld L1-N V
Trip:ld L2-N V
Trip:ld L3-N V
Trip:ld L1-L2 V
Trip:ld L2-L3 V
Trip:ld L3-L1 V
The IPC tripped its main circuit breaker because the voltage between the indicated pair of terminals, on the load side, exceeded 125% of the IPC's voltage rating.

Trip:N-G Voltage
The IPC tripped its main circuit breaker because the voltage between the neutral terminal, on either the load side or the source side, and the Ground (protective earth) terminal, exceeded 125% of the IPC's voltage rating.

Trip:PE curr ld
The IPC tripped its main breaker because the current flowing in the Protective Earth (ground) terminal, on the load side, exceeded the IPC's programmed limit.

Trip:PE curr Pwr
The IPC tripped its main breaker because the current flowing in the Protective Earth (ground) terminal, on the IPC's power cord, exceeded the IPC's programmed limit.

Trip:PE curr src
The IPC tripped its main breaker because the current flowing in the Protective Earth (ground) terminal, on the source side, exceeded the IPC's programmed limit.

Trip:src L1 Amps
Trip:src L2 Amps
Trip:src L3 Amps
Trip:ld L1 Amps
Trip:ld L2 Amps
Trip:ld L3 Amps
The IPC tripped its main circuit breaker because the current on at least one of the source ("src") or load ("ld") terminals. There are three different overcurrent limits: an instantaneous limit, typically 600 amps; a single-cycle limit, typically 300% of the trip current setting; a 75-cycle limit, typically 200% of the trip current setting; and a 250-cycle limit, typically 125% of the trip current setting.

Trip:src L1-N V
Trip:src L2-N V
Trip:src L3-N V

Trip:src L1-L2 V
Trip:src L2-L3 V
Trip:src L3-L1 V

The IPC tripped its main circuit breaker because the voltage between the indicated pair of terminals, on the source side, exceeded 125% of the IPC's voltage rating.

Trip:Stuck0 RLNN

The IPC tripped its main circuit breaker because the one of its internal relays, indicated by NN, failed to transition from its "off" state to its "on" state in the time allowed by the IPC. The relay may be defective, or it may need mechanical re-alignment. Service is required. Contact the factory.

Trip:Stuck1 RLNN

The IPC tripped its main circuit breaker because the one of its internal relays, indicated by NN, failed to transition from its "on" state to its "off" state in the time allowed by the IPC. The relay may be defective, or it may need mechanical re-alignment. Service is required. Contact the factory.

Turn Brker on.

If it is safe to do so, turn the main circuit breaker on. It is located on the back of the IPC, in the center.

Turning Brkr on.

This message only occurs if your IPC has the motor-operated circuit breaker option. It shows that the motor is in the process of turning on the main circuit breaker, on the back of the IPC.

Waiting for PC.

The IPC is ready to begin communication with a Windows PC running the IPC software package. (Under certain circumstances – after a lengthy communication interruption — this message may appear even when the IPC and the PC are communicating. Press the "disconnect" button on the IPC software package, then reconnect.)

Xfrm NNNC ovrtemp

The IPC's internal transformer is NNN degrees C over its programmed temperature limit, probably due to a rapid sequence of lengthy, high current sags or swells. Allow it to cool. It will automatically clear this error message when it is no longer over its temperature limit.

B - Software error messages

"Your computer is running too slow for once-per-second power readings. The readings will be updated as rapidly as possible."

Most recent event terminated due to no setup"
MostRecentEventOutcomeStrings(2) = "Most recent event terminated due to panic"
MostRecentEventOutcomeStrings(3) = "Most recent event terminated due to blown snubber fuse"
MostRecentEventOutcomeStrings(4) = "Most recent event terminated due to IGBT fault"
MostRecentEventOutcomeStrings(5) = "Most recent event terminated due to overheating relay"
MostRecentEventOutcomeStrings(6) = "Most recent event terminated because event was canceled"
MostRecentEventOutcomeStrings(7) = "Most recent event terminated because no zero crossing was found"

Command N was rejected by processor N

Appendix B - Specifications - general

General specifications

Functional	Voltage Sag/Dip and Swell testing per SEMI F47, IEC 6100-4-11, CBEMA, ITIC, MIL STD, FAA, SAMSUNG, and other international standards. With Power Flow Analysis option, also performs to SEMI E6, current inrush testing, harmonic current testing, and more.
Agency approvals	Designed to meet U.S. and Canadian safety standards, CE certification requirements, FCC requirements. Fully meets requirements of IEC-1010, and IEC-61000-4-11. Fully meets requirements and recommendations of SEMI F47.
Equipment ratings	Rated as Class I equipment. Rated for Installation Category II (local level, appliances, portable equipment). Rated for Pollution Degree 2 (Normally, only non-conductive pollution occurs.)
Operating environment	Indoor use. Altitude up to 2000 m. Temperature between 5°C and 40°C. Max relative humidity 80% for temperatures up to 31°C decreasing linearly to 50% relative humidity at 40°C.
Instrument Power	100 to 240 Vac (±10%), 50/60 Hz, 4 Amps max.
Software	Industrial Power Corruptor program for setup/operation of IPC, viewing real-time and downloaded data, and collecting information for test report generation. With Power Flow Analysis option, software includes vector scope, real-time oscilloscope, and real-time spectrum analyzer. ChannelScope II software for viewing, zooming, scrolling, and synchronizing power waveforms. FlowScope software for graphing and examining power flow over time. Requires PC with Windows 98 or XP.
Communications	Front panel RJ-45 jack for serial connection to PC.
Physical	19 inch rack-mount unit in rugged polyethylene case measuring 21in. W x 11in. H x 30 in.L (50cm x 28cm x 76cm). 130lb (59Kg)

Permissible Test Conditions

Voltage Range	100 – 480 Vrms, 50 or 60 Hz, 1-phase or 3-phase. Voltage is limited to 240Vrms on some model numbers.
Voltage Configuration	Single phase or 3-phase (Y or delta) connection to unit. Voltage dropout testing can occur on all phases simultaneously. Voltage sag and swell testing on a single pair of phases, or phase to neutral. Phase selection for events is done with front panel dial.
Load Current	Up to 200 Amps per phase continuous, depending on model number. 600 Amps peak. Front panel dial for user selection of current trip point.

Voltage Sag / Swell Testing

Magnitude	0% to 125% of nominal voltage in 2.5% steps. User can select 0% sag to be either high impedance or low impedance.
Duration	User selected duration from 0.1 cycles to 34 seconds in 0.1 cycle steps.
Magnitude/Duration Margin	A front panel switch allows quick 5% or 10% increase in event magnitude and duration.
Phase Angle	0 to 359 degrees in 1-degree steps.
Event Trigger Input/Output	Manual front panel “Arm” and “Fire” switches locally trigger event. Rear panel BNC connectors provide bi-directional 24V logic level (falling edge) trigger output and input capability.
Semiautomatic Sequencing	As well as manual event configuration, the user can semi-automatically step through a industry standard recipe on a single or 3-phase system.
Switching Method	High speed, gapless switching, IGBT package with patent-pending override design for long duration events.

Three Phase Voltage Dropout and Current Inrush Testing

Magnitude	Full voltage and current rating of Industrial Power Corruptor
Max instantaneous current recording	±1 000A instantaneous
Interruption Duration	0.3 to 34 seconds.
Phase angle	0 degrees to 355 degrees in 5 degree steps. Referenced to user selected voltage channel.
Switching Method	Mechanical relays, with calibrated switching times to 0,4 milliseconds

Data Acquisition

Internal Analog Input Channels	13 internal voltage channels, 6 internal current channels, 3 protective earth current monitoring channels.
External Analog Input Channels	3 front panel ±600V (AC or DC) channels, 6 front panel ±100V (AC or DC) channels.
Analog Input Viewing	Three front panel meters (including min. and max. values) can be selected to display any data acquisition channel in real time. Alternatively, these channels can be monitored using a connected PC and the software provided.
Resolution	15 bits equivalent per individual sample on 1000V / 1000A channels, 12 bits per individual sample on other channels, 16 bit equivalent for average and RMS measurements
Accuracy	Guaranteed accuracy ±1,0% FS on voltage and current. Typical accuracy ±0,25% FS (voltage and current), ±0,5% FS (power parameters), ±1,0% FS (harmonics), ±1° (between any voltage and current channel)
Sampling Rate	0.8 KHz to 7.68 KHz
Phase lock	With Power Flow Analysis option, software phase-lock to user-selected voltage channel – for precision harmonic and power flow calculations

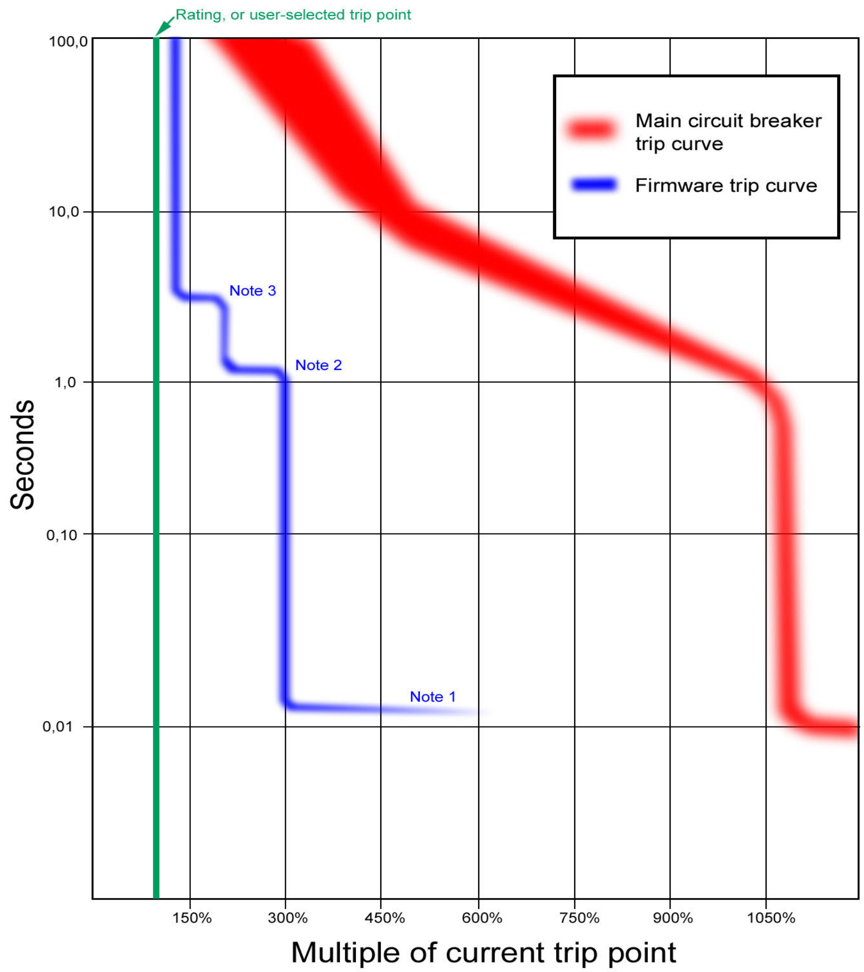
Standard accessories included

CD-ROM	Includes the latest software and diagnostics for the IPC, and the IPC User's Manual
Power cord	IEC-compatible power cord with North American plug
BNC caps	Protective, military-style metallic caps for every front-panel BNC connector
Wire Adapters	Set of 10 custom designed wire adapters required for connection to terminal blocks when using smaller gauge wire.
Communication cable	RJ-45 to DB-9 serial communication cable for connecting IPC to serial port on Windows computer
Re-useable shipping crate with custom padding	Custom, furniture-grade wooden shipping crate, with high-density fitted foam inserts and external shock absorbing feet. Wing-nut fasteners for easy re-use. The IPC must always be shipped in this case.

Options

Circuit Breaker Motor Operator	Customized motor operator to operate circuit breaker handle from front panel switch operation. Required for rack-mount installations. Recommended for safety enhancement.
Power Flow Analysis package	Software package for detailed power analysis and harmonics analysis. Includes FlowScope graphing program for reviewing downloaded data, real-time Vector Scope, real-time oscilloscope, real-time spectrum analyzer. Optimized for recording power consumption of industrial processes, including SEMI E6.
Upgrade from 240V-25A to 480V-50A	Increases continuous current from 25 amps to 50 amps, and increases voltage rating from 240V to 480V. Requires brief return-to-factory for various internal upgrades.
Upgrade from 480V-50A to 480V-100A	Increases continuous current from 50 amps to 100 amps. Requires brief return-to-factory for various internal upgrades.
Upgrade from 480V-100A to 480V-200A	Increases continuous current from 100 amps to 200 amps. Adds "combat mode" for extended capabilities. Requires brief return-to-factory for various internal upgrades, including additional fans.
Laptop controller	Strongly recommended. A Windows PC laptop, pre-loaded with all IPC software, and pre-configured for immediate use. Eliminates any questions about computer compatibility.
Additional Wire Adapters	Set of 10 custom designed wire adapters for connection to terminal blocks when using smaller gauge wire.
Additional communication cable	RJ-45 to DB-9 serial communication cable for connecting IPC to serial port on Windows computer
Test lead kit	Set of high and low-voltage connectors and cables for typical external data acquisition.
Replacement shipping crate with custom padding	Custom, furniture-grade wooden shipping crate, with high-density fitted foam inserts and external shock absorbing feet. Wing-nut fasteners for easy re-use. The IPC must always be shipped in this case to reduce chance of damage from shock and vibration.

Appendix C - Specifications - Maximum allowable current



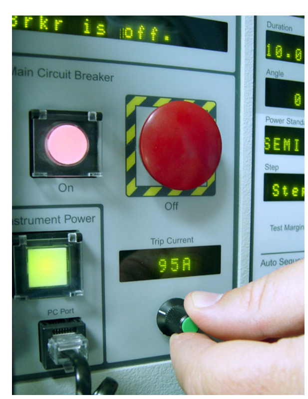
Note 1: During a sag/swell event, there is a 600-amp instantaneous trip point. On IPC's rated for 200 amps, this trip point can be increased to 700 amps by placing the IPC into Combat Mode.
Note 2: The time for this threshold is frequency-dependent. It is set to 75 consecutive cycles.
Note 3: The time for this threshold is frequency-dependent. It is set to 250 consecutive cycles.

Your IPC's main circuit breaker has an internal trip curve, shown in red on the graph above.

The firmware in your IPC watches the current on each of the three source-side phase terminals, and each of the three load-side phase terminals. It will trip the main breaker if any of these currents, based on average-sense RMS calibration, exceed the following limits: 300% of the front-panel current trip point for a single cycle, or 200% of the front-panel current trip point for 75 consecutive cycles, or 125% of the front-panel current trip point for 250 consecutive cycles.

In addition, during a sag or swell event, the firmware will trip the main breaker if the absolute value of any single current sample exceeds 600 amps, regardless of the IPC rating or the front-panel current trip point. (IPC's that are rated for 200 amps have a Combat Mode - in Combat Mode, this limit is increased to 700 amps.)

In addition, the firmware will trip the main circuit breaker if any phase-to-phase or phase-to-neutral voltage exceeds 550Vrms (for IPC's rated at 480V) or 300Vrms (for IPC's rated at



The blue curve is controlled by the front-panel Trip Current setting.

240V) for a single cycle.

Here is a complete list of reasons that the IPC may trip its main circuit breaker:

1. Overcurrent on any source or load phase conductor (see discussion on previous page)

2. Overvoltage between any pair of phases, or between any phase and neutral (see discussion above)

3. Inherent breaker trip curve (see red portion of curve on previous page)

4. Current on Source Protective Earth terminal exceeds 500mA AC

5. Current on Load Protective Earth terminal exceeds 500mA AC

6. Current on power cord ground terminal exceeds 500mA AC

7. “Panic” signal asserted on rear-panel BNC connector

8. One or more of the 31 main relays is stuck on

9. One or more of the 31 main relays is stuck off

10. Red “Off” mushroom-cap button pressed on front panel of IPC

11. Instrument power is removed, or turned off

12. Throughout the IPC’s start-up sequence

13. Failure of the IPC’s internal communication network between its Control Processor and any of the other five processors.

14. (If breaker motor-drive option is installed): more that 5 seconds have elapsed while trying to change the state of the breaker to ON without succeeding.

The following events do not trip the main circuit breaker, but always immediately terminate any disturbance event:

1. Transformer temperature exceeds 80°C.

2. Bypass relay temperature exceeds 80°C.

3. IGBT-generated fault (either IGBT overcurrent shutdown, or damaged IGBT).

4. Event cancelled by user pressing either of the two fornt-panel “Stop” switches

5. No zero-crossing found on the source side of the selected event phase, after waiting at least 25 milliseconds.

6. One or more of the fuses on the IGBT snubber board is/are blown

Appendix D - Theory of Operation

The IPC is inserted between an AC power source and Equipment Under Test (EUT).

Power terminals on rear panel:

The power terminals are grouped into "source" and "load" terminals. Each set of terminals can accept up to three (3) phase conductors, an optional neutral conductor, and a required protective earth conductor. All of the terminals are internally connected to 0,5 inch bus bars. The three source-side phase terminals pass through current transformers, then are connected directly to the main circuit breaker. Spring-loaded contacts pick up the source and load voltages. The three load-side phase terminals also pass through current transformers. Both protective earth terminals are connected directly to the IPC chassis, and pass through PE current sense transformers. If more than 500mA is detected on either PE terminal, the panic signal is asserted.

Main circuit breaker:

The main circuit breaker includes three trip mechanisms: a fast magnetic trip, a slow thermal trip, and a shunt trip. The shunt trip is activated whenever the red front panel Off button is pressed, and whenever the Panic signal is asserted for any reason.

Phase configuration relays:

These sixteen electro-mechanical relays connect the source power terminals and the load power terminals appropriately. They can bypass the IPC completely, or they can connect any phase, or pair of phases, as inputs or outputs to the sag/swell generator section. These relays are also used for three-phase interruptions; the operate and release time of each relay is factory calibrated in flash memory, so precision phase angles can be obtained.

Power up sequence:

The IPC begins by shunt-tripping its main circuit breaker, for safety reasons. Then the Control Processor, which manages all of the firmware, boots up each of the other four processors, and loads them with their firmware. Finally, the Control Processor turns its attention to the front-panel serial port and waits for communication from the IPC program running on a Windows computer.

Internal communication and control:

In general, each circuit board on the IPC has at least one processor, and each processor has at least one 4-channel serial communications chip. Serial communications was chosen to maximize reliability and to minimize noise problems. In addition to the serial communications between processors, three open-collector negative-true signals are routed throughout the IPC: arm, trigger, and panic. These three signals are available on BNC terminals on the rear of the IPC. The arm signal is asserted by the Relay Processor prior to performing an event. The trigger signal goes low at the precise beginning of an event, and returns high at the precise end of an event. The panic signal trips the main circuit breaker through its shunt-trip mechanism.

Power for the IPC:

Power for the IPC enters an IEC connector at the bottom left of the back panel. It immediately passes through a high-frequency noise filter, then progresses by cable to the Power Supply board. The earth connection on this cable passes through a current transformer; if 500 mA or more is ever detected on the earth conductor, the Power Supply board asserts the Panic signal, and the main circuit breaker is tripped. On the Power Supply board, the AC supply is fused on both line and neutral, and has MOV surge suppressors. From the Power Supply board, the AC supply then passes through a cable to the Front Panel Board, where the IPC on/off switch is located. AC returns from this switch, on the same cable, to the IPC power supply. The IPC has a single 24V dc power supply. 24Vdc from this supply is brought to the Power Supply Board via a short jumper cable. Several large electrolytic capacitors on the Power Supply Board back up the 24V dc. Each separate circuit board in the IPC has one or more switching regulators to convert the +24Vdc to +5Vdc, +/-12 Vdc, and/or +/-15 Vdc. Some of these switching regulators provide isolation and floating signals for communication.

External communication and control:

The IPC communicates serially at 115k baud to a Windows program running on a user-supplied computer. The serial communication ports are all floating from earth, with at least 1kV of isolation. The Ethernet port also floats with 1kV of isolation. Three control signals are available on rear-panel BNC connectors: Panic, Arm, and Trigger. All three are open-collector, active-low signals, weakly pulled up internally to +24V. Panic may be asserted externally by shorting the Panic connector. Arm and Trigger may be used externally to trigger data acquisition devices.

Data acquisition:

The IPC contains many differential-input data acquisition channels. The standard full-scale ranges are ±1000V , ±100V, and ±1000A. The channels are fully differential, and are equipped with 5kHz low-pass filters. A variety of A/D schemes yield effective resolutions ranging from 12 bits plus sign to 16 bits plus sign. For Power Flow mode, the IPC phase-locks its 128-sample-per-cycle to the L1-N channel (if N is not in use, this is effectively L1-PE). For Disturbance Mode, no sampling is used. For breaker trip monitoring, average-sense RMS-calibrated 16-sample-per-cycle is used. All offset calibration is performed in firmware, using factory-set constants stored in Flash. No gain calibration is required.

Sag/swell generation:

The IPC uses a patent-pending multiple-tap auto-transformer to generate sags and swells. The transformer has the equivalent of taps at every 2.5% from 0% to 125%. Relays configure the taps, and connect the transformer to the appropriate phases and neutral if necessary. A pair of IGBT switches transfer the output from the 100% tap to the selected tap, then back to 100% tap at the end of the event. Using a patent-pending technique, the IGBT's are bypassed by electromechanical relays during the event, to minimize power dissipation, allowing the IGBT's to be used only during the transitions. The IGBT module has a patent-pending set of snubber circuits, which include fuses. Optically-isolated sensors detect if any of the fuses have operated. The IGBT module also monitors its internal temperature and overcurrent limits.

Protective earth:

The IPC senses current on every protective earth terminal, and asserts Panic (i.e. trips the main breaker) if excessive current is observed. Every element of the IPC chassis and enclosure has a dedicated, solid copper buss link connecting it to protective earth.