

## Introduction

Electric motors, incandescent lighting, switching power supplies, and other transformer/rectifier input electronic devices typically draw a high level of peak inrush current from the AC power line on start-up as the input capacitors charge and magnetic fields are established. Peak amplitudes of the inrush current vary with the phase-angle of the ac voltage cycle. To determine worst case current inrush conditions, it is necessary to be able to control the phase angle of the ac voltage cycle at start-up, and measure the resulting peak amplitude of current drawn.

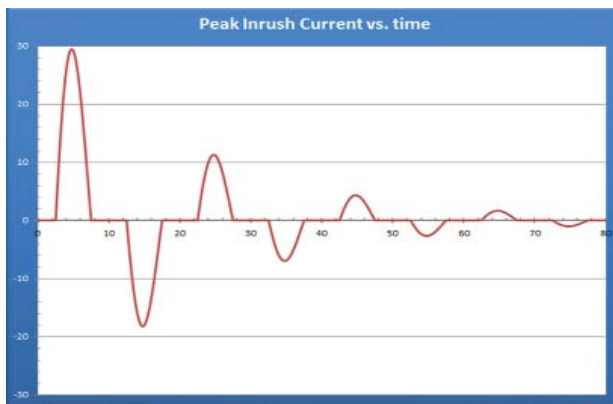


Figure 1: Typical Inrush Surge Content of an AC Powered Product

An example of a typical AC inrush surge current is shown in Figure 1. The first half cycle shows the highest inrush current. As the capacitors of the AC input supply charge up, the inrush current declines with each half cycle of the AC voltage waveform. Most products will have some provision in the input circuit to limit this initial inrush current at power on to an acceptable value. Such provision are generally referred to as 'soft-start' or 'inrush limit' circuits.

Peak current surge current measurements can be accomplished using the UPC Test Manager software to create and execute specific start phase angle transients in combination with the built in metering capability of any of the UPC controllers.

However, developing up a test program is not always convenient or expedient unless the need to perform this test is repetitive as in a production test application.



To facility making these types of measurements more quickly, the PEAK CURRENT OPTION can be added to a new or existing Pacific Power Source product equipped with UPC1 or UPC3 controller. With this option installed inrush current measurement at specific programmed start phase angles are readily made from both the front panel or over the remote control interface.

## Peak Current Surge/Inrush Measurement

The peak inrush option provides a method to display power source peak current measurements for single-phase, split-phase, or three phase configurations. An arm/disarm mechanism is controlled either from the UPC's front panel or by a remote interface control program using SCPI commands. One UPC-1/3 display screen shows the peak value(s) and the arm/disarm setting. The UPC continues to operate the power source and normal UPC operations may be conducted while peak current surge inrush measurement is armed with the exclusion of other metering operations (this includes V/I METER, POWER METER, AMPS METER, AND CSC).

The Peak Current detection measurement can be initiated from the front panel of the UPC-1/3 or through a remote communication interface (RS-232 serial or GPIB/IEEE-488 depending on model). Both methods provide the user with control mechanisms to arm and disarm peak current capture and view the peak value(s) which are detected.

Single phase, split-phase, or three phase operation are all supported and automatically selected, based on the active UPC configuration. For example, with a UPC-3 set for three phase operation, peak current capture and display operation will be performed on all three phases simultaneously.



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## Features-Peak Current Measurement

- Integrates into any UPC-1 or UPC-3 Power Source without hardware modification.
- Other UPC-1/3 options may be combined with surge inrush option.
- Front panel or remote bus control arms, disarms, and displays surge inrush peak current capture process.
- Peak current values are captured in real-time and displayed in real-time, as follows:
  - The system meters current only, all other metering is suspended.
  - Current is sampled every 20 usec for the duration of the process.
  - Single-phase output is sampled at the full rate of 20 usec./measurement.
  - Three-phase outputs share the sampling and therefore each phase is sampled at 60 usec./ measurement.

## Manual Operation-Peak Current Measurement

The INRUSH METER is grouped with the other UPC METER display screens, ordered as follows:

- V/I METER
- POWER METER
- MPS METER
- INRUSH
- HARMONIC ANALYSIS (option)

The V/I METER is the Primary display with other metering displays invoked by pressing the "DISPLAY" key repeatedly until the desired meter is displayed.

From the primary display of a UPC-3 power source controller configured for three-phase operation, pressing the "DISPLAY" key three times will display the following screen:

INRUSH METER:	PHASE A	PHASE B	PHASE C
PEAK CURRENT	000.00	000.00	000.00
PRESS +/- TO ARM	STATUS: DISARMED		

Pressing the "+/-" key will "ARM" (or "DISARM") the INRUSH METER. This will initiate a continuous sampling process and display peak currents captured for each phase for the duration of the process.

Maximum current values are sampled and displayed in real-time as scaled AMPS. Only peak "absolute" values will be displayed. Values displayed will be zero when the meter is DISARMED. The captured process will begin immediately when ARMED and continue until DISARMED.

Refer to examples in the Programmable Phase Angle Execution section of this document, for a description of how peak current capture can be used along with phase angle execution control to conduct surge inrush analysis.

The following screen is displayed when peak current capture is armed:

INRUSH METER:	PHASE A	PHASE B	PHASE C
PEAK CURRENT	38.21	38.20	38.17
PRESS +/- TO ARM	STATUS: ARMED		

Options available from the INRUSH METER screen:

- Pressing the +/- key again will disarm the peak current capture process and display "STATUS: DISARMED", all displayed values will then go to zero.
- Pressing the PROGRAM key will display the PROGRAM EDIT/ EXECUTE menu for editing and executing programs and editing transient events associated with each program. Upon execution of a program, storing of an edited program and or transient, or pressing CLEAR the display will return to the INRUSH METER. The STATUS remains ARMED.
- Pressing the fn key will display the SETUP MENU, peak current capture remains ARMED. From here users may invoke any set up functions described in the UPC-1/3 Operation Manual, with the exception of CSC (Continuous Self Calibration), which will not operate when the INRUSH METER is ARMED.
- Pressing the CLEAR key will automatically DISARM the INRUSH METER peak current capture process and return to V/I METER where normal metering will resume.

- Pressing the DISPLAY key will advance the screen to HARMONIC ANALYSIS if that option is installed; otherwise, the UPC controller will automatically DISARM the INRUSH METER peak current capture process and return to the V/I METER where normal metering will resume.
- Pressing the TRANS key will execute any transient segments associated with the program presently executing. Refer to the UPC Operation Manual for details on setting up and executing transients.

The phase angle may be controlled from the front panel via the program edit display which contains an additional field for voltage change at "EXEC  $\Phi$ =xxx" degrees.

A unique execution phase angle may be associated with each of the 99 user programs.

### Manual Operation-Phase Angle Exec.

The existing front panel controls for program editing are used as described in the Operation Manual for

The SCPI commands added to the UPC-1/3 to support these options are:

:SOURce: INRUSH:STATE <b>	Command: Arms/Disarms peak current inrush metering. <b> = 0 [OFF] or 1 [ON] Requires a Boolean argument, either a binary value or plain language state descriptor.
:SOURce: INRUSH:STATE?	Query: Returns a Boolean indicator, state of inrush metering. 1=armed, 0=disarmed
:MEASure: CURRent: PEAK1?	Query: Returns numeric value, Peak Current in amps. PEAK1 specifies Phase A or Single Phase amps. If Peak Inrush Metering is ARMED, peak current measurement obtained from fast metering will be returned; otherwise, peak current value obtained from normal metering will be returned
:MEASure: CURRent: PEAK2?	Query: Same as above. PEAK2 specified Phase B amps.

### Remote Operation-Peak Current

Peak Inrush Metering, like other UPC functions, may be operated remotely via either a SERIAL or an IEEE-4888/ GPIB connection. The SCPI standard for instrumentation command language syntax is used to provide a seamless interface for remote operations (see Sec. 5 of the Operation Manual).

### Programmable Phase Angle Execution

The standard UPC-1/3 controller always begins execution of programs and transients at the positive zero crossing (0 degrees) of phase A. The voltage of the sine wave is therefore always 0 volts at the beginning of operation. Loads which draw high inrush currents do not exhibit worst case behavior in that condition.

The Programmable Execution Phase Option provides the capability to specify the phase angle for phase A voltage to begin when a program is executed. The default setting is phase = 0 degrees of phase A, the same as the standard program. By setting the beginning phase angle to occur closer to the peak of the waveform, inrush behavior can be tested under various conditions, as the output voltage will transition to the peak value more rapidly.

UPC-1/3 controllers, with the exception that the phase angle at time of execution is specified. The modified PROGRAM EDIT display is:

#### SINGLE PHASE CONFIGURATION

PROGRAM: #4	FORM=1	COUPLING=DIRECT
FREQ=60.00	V=120	
EXEC $\Phi$ =90	WF=1	
#SEGS=0	Ilim=30	

#### THREE PHASE CONFIGURATION

PROGRAM: #4	FORM=3	COUPLING=DIRECT
FREQ=60.00	Va=120	Vb=120 Vc=120
EXEC $\Phi$ =90	WFa=1	WFb=1 WFc=1
#SEGS=0	Ilim=30	PHb=120 PHc=120

All keyboard operation of the controller remains the same or similar to the standard configuration.

When executed, the program will begin generating the specified RMS voltage at the specified ("EXEC  $\Phi$ =") phase angle of phase A voltage waveform.

## Remote Operation-Phase Angle Exec.

Phase Angle Execution, like other UPC functions, may be operated remotely via either a IEEE-4888/GPIB or a SERIAL connection. The SCPI standard for instrumentation command language syntax is used to provide the user a seamless interface for remote operations (see Section 5 of the Operation Manual).

The Programs used below can be accessed from any of the metering displays but for this example we will begin with the INRUSH METER screen and manipulate our programs from that meter. This will return us to the INRUSH METER each time a program action was completed, rather than to the V/I METER or other meter displays.

The SCPI commands added to the UPC-1/3 to support these options are:

:SOURce: PHASe1 <n>	Command: Sets the execution phase angle for phase A. Values for <n> are integral degrees with range: 0 to 359. The presently executing program is set to the specified angle <n> and (re) executed using the new execution phase angle.
:PROGRam[:SELEcted]:DEFine	<program> Command: Defines Program parameters. See para. 5.3 of the UPC-1/3 Operation Manual. The PHASe1 <n> command has been added to <program> as a steady-state output parameter, specifying execution phase angle in integral degrees with a range from 0 to 359. PHASe1 differs from the existing PHASe2 and PHASe3 phase angle controls by being a one time only event.  PHASe1 is not a steady-state output parameter. It specifies the phase angle of phase A at the instant of execution only.  PHASe2 and PHASe3 specify the steady-state phase delay of phase B and phase C relative to phase A. For typical three phase operation, phase B is at 120 degrees and phase C is at 240 degrees.  NOTE: Execution phase angle should not be confused with transient segment parameters.
:PROGRam[:SELEcted]:DEFine?	Query: Execution phase angle Returns as PHASe1 along with all other steady-state output parameters.
:PROGRam: EXEcute:	Command: Execute the selected Program. See para. 5.4.1 of the UPC-1/3 Operation Manual. Any set Execution Phase Angle will be used upon program execution.

## Examples

Two examples of how Peak Inrush and Execution Phase Options can be used together to analyze surge current inrush are shown below. Single-phase examples are shown for:

- (1) operation from the UPC front panel and
- (2) remote operation (GPIB or SERIAL) via the SCPI command language.

Three-phase operation is accomplished similarly. Both examples demonstrate explicitly how to capture the peak surge current.

### Front Panel Operation:

Programs (and transients) can be created, viewed, stored, and/or executed from any of the meter display screens.

Beginning from the V/I METER:

```
V/I METER
FREQ=60.00      V=120
SENSE=INT
MANUAL MODE     I=12.00
```

PRESS> DISPLAY, DISPLAY, DISPLAY

To show the INRUSH METER display.

```
INRUSH METER:  PHASE A
PEAK CURRENT   00.10

PRESS +/- TO ARM      STATUS:   ARMED
```

Verify that the STATUS is ARMED.

PRESS> PROGRAM

```
PROGRAM: #1      FORM=1      COUPLING=DIRECT
FREQ=60.00      V=120
EXEC Φ=0        WF=1
#SEGS=0         Ilim=30
```

The display will show the Program that was most recently edited.

Create a program and set the programmed voltage amplitude to zero:

PRESS> 9, ENTER, EDIT, ENTER, ENTER, 0, ENTER, 90

```
PROGRAM: #9      FORM=1      COUPLING=DIRECT
FREQ=60.00      V=0
EXEC Φ=0        WF=1
#SEGS=0         Ilim=30
```

Execute the newly created program #9. This will store the program and begin producing an Output of zero volts to simulate a power-off condition:

PRESS>EXECUTE

```
INRUSH METER: PHASE A
PEAK CURRENT   00.10

PRESS +/- TO ARM      STATUS:   ARMED
```

This returns us to the INRUSH METER display

To initiate a power start condition at a specific phase angle, create a program and set the desired output voltage amplitude and execution phase angle, such as:

PRESS> 10, ENTER, EDIT, ENTER, ENTER, 120, ENTER, 90

```
PROGRAM: #10     FORM=1      COUPLING=DIRECT
FREQ=60.00      V=120
EXEC Φ=90       WF=1
#SEGS=0         Ilim=30
```

Program 10 is now ready to produce a 120 volt, 60 Hz output, starting at 90 degrees (the positive peak) of the first sine wave. The power source continues to operate at zero volts (Program 9 is still active).

NOTE: The "Ilim=" should be set to the maximum value allowed by the power source, otherwise the supply may limit the current and the inrush peak may not be consistent with real power-line conditions. It is also important that the power source have enough power to provide the peak current required by the load.

PRESS>EXECUTE

```
INRUSH METER: PHASE A
PEAK CURRENT   11.36

PRESS +/- TO ARM      STATUS:   ARMED
```

Peak current caused from turn-on at a voltage A phase angle or 90 degrees will be captured and displayed in real-time. The peak current value will be continually updated, if higher currents are detected.

Multiple tests can be run to determine exact peak surge current inrush for different execution phase angles using a simple, iterative process such as the following:

- a) Execute program number 9
- b) Edit the EXEC Φ= and/or voltage for program number 10
- c) Execute program number 10

### Remote Interface Operation:

Similar results may be achieved by remote operation of the UPC using SCPI commands issued over a parallel or serial bus connection. Refer to section 5, GPIB and REMOTE OPERATION, and section 10, RS-232 SERIAL REMOTE INTERFACE, of the UPC-1/3 OPERATION MANUAL for detailed information on remote operation of the UPC.

The following programming example will perform the same test described for manual operation in the preceding example except only one program is explicitly defined. The simulated off state will be produced using the [:SOURce] command. Command keywords shown in square brackets, such as [:SOURce], are optional. Likewise, all lower-case characters are optional.

First we create a program which will be used to define the turn-on state. This program will be initialized with nominal steady-state power source configuration directives, along with the specification for an execution phase of 90 degrees. It is created and stored for later usage.

```
:PROG:NAME 10;
:PROG[:SElected]:
    FORM,1,
    COUPLing,1,
    XFMRratio,2,0,
    FREQuency,60,
    VOLTage,120,
    CURRent:LIMit,50,
    PHAse1,90,
    WAVEFORM,1,
    EVENTS,0;
```

**NOTE:** The :PROG:DEF command parameters must be transmitted as a consecutive string without any CR/LF characters.

Set the power supply output voltage to 0 to simulate a power-off condition:

```
[:SOURce]:VOLTage 0;
```

Arm INRUSH metering:

```
[:SOURce]:INRUSH:STATE ON;
```

Execute program number 10:

```
:PROG:Name 10;:PROG: EXECute;
```

Obtain the captured peak current with a query after allowing some time for the surge inrush and peak current capture to occur by supplying a programmed delay period:

```
:MEASure:CURRent:PEAK1?
```

The returned value will be the peak current captured during the surge resulting from the simulated turn-on at 90 degrees.

The :MEAS:CURR:PEAK1? Query may be repeated to check for updated data.

## Ordering Information

The Peak Inrush Option can be ordered as a separate line item when ordering any Pacific Power Source ASX, AMX or MS Series AC Power Source equipped with the UPC1 or UPC3 controller. Not available on models equipped with UPC12 and UPC32 controllers. This option adds special firmware and hardware modifications to support the measurement and phase angle control capability described in this application note.

To upgrade existing Pacific Power Source units with this option, contact customer service and provide the exact model and serial number of the unit you would like to add this option to so we may provide you with an upgrade quotation.



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