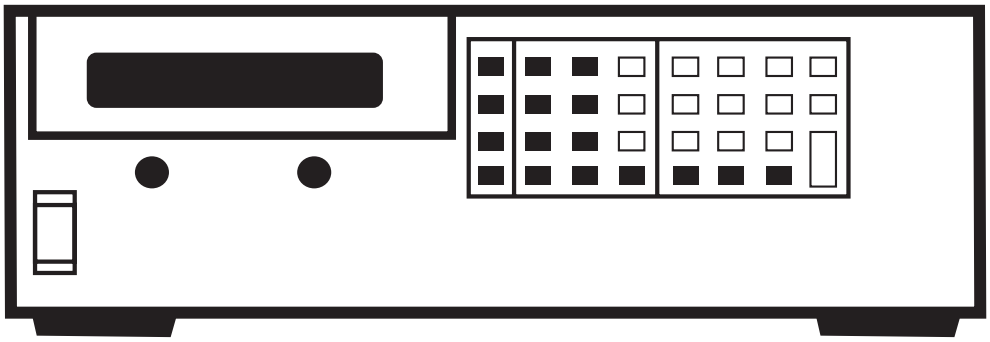
Agilent 6800 Series
ac Power Source/Analyzers

Product Note



Testing Uninterruptible Power Supplies Using Agilent 6800 Series ac Power Source/Analyzers

Includes Dual Power Analyzer option discussion

Ensuring that Uninterruptible Power Supplies (UPS) are designed and operating properly is essential to guarantee that the UPS will satisfactorily protect sensitive equipment against ac mains voltage abnormalities. Agilent Technologies ac power source/analyzers can be used to help test UPS's in many different environments, including research and development, manufacturing, and incoming inspection.

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There is a lot of competition in the UPS business. Therefore, it is important for UPS manufacturers to fully characterize and test their UPS products, ensuring that their customers will be satisfied with the products they purchase. Whether the UPS is an off-line, line-interactive, or on-line design, Agilent ac sources can help produce a robust design and verify proper operation.

Since the major purpose of a UPS is to properly respond to ac mains voltage fluctuations, UPS testing is incomplete without a reliable method of simulating the various power problems that can occur on the ac mains. Complete testing includes subjecting the UPS to these fluctuations while noting the UPS output response.

Power surges, power sags, missing line cycles, clipped sine waves, noise voltages, frequency variations, brownouts, and blackouts are just some of the abnormalities that can occur on the mains. (See Figure 1.) Each of these can be produced with Agilent ac sources. With the source connected to the UPS ac input, the UPS output response can be evaluated using Agilent's built-in Dual Power Analyzer option, providing extensive measurement capabilities using rear panel inputs for voltage and current (measured through a supplied current shunt). UPS transfer time, phase difference between UPS input and output voltage, UPS efficiency, and UPS peak output voltage are just some of the measurements that can be made with this option, discussed more later. These external measurement capabilities are in addition to the standard measurement capabilities of all Agilent ac sources that provide measurements on the ac source output voltage and current.

Measurements made on all four measurement channels (ac source output voltage and current, and Dual Power Analyzer voltage and current inputs) are inherently synchronized with the ac source output waveform. Without the Dual Power Analyzer option, other test equipment such as a voltmeter and an oscilloscope would be required to measure the UPS output response in order to test the effectiveness of the UPS protection against ac input voltage fluctuations. The capabilities of Agilent ac sources can be accessed either through the front panel for bench-top testing, or over the built-in GPIB or RS-232 interface for automatic test stations.

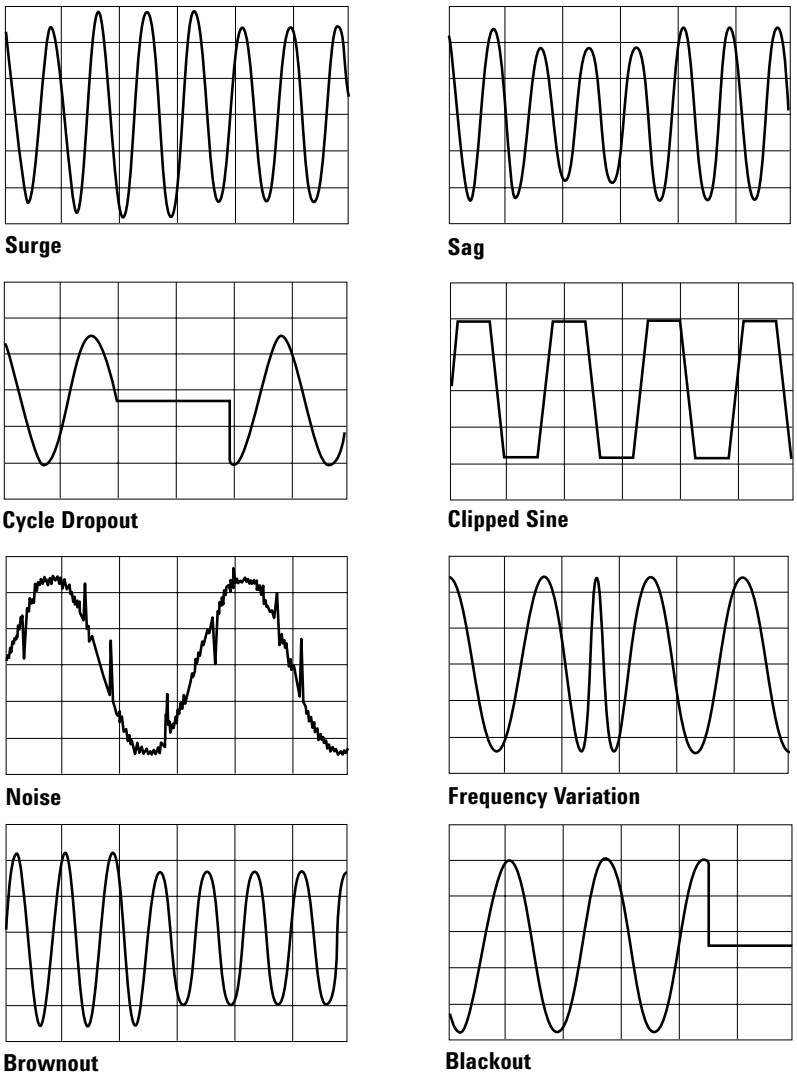


Figure 1. UPS's protect against these ac mains voltage disturbances. Agilent ac sources can produce each of these waveforms to test the UPS.

Many UPS specifications can also be checked by using an Agilent ac source as the power source for the UPS. To simplify the measurement setup, the Dual Power Analyzer option can be used to provide the UPS *output* measurements. These UPS specifications include:

- input voltage range,
- input frequency range
- output voltage and frequency accuracy with various input voltages and frequencies

- peak output voltage transfer time
- input frequency autosense capability
- line voltage alarm settings
- alarm delay settings
- turn-on delay settings
- low voltage transfer point
- high voltage transfer point
- UPS input current
- UPS input power
- efficiency
- power factor
- UPS front panel indicators for line voltage, on-line, on-battery, voltage boost, and voltage reduction.

Since the output of Agilent ac sources is isolated from ground, either output terminal may be connected to ground making it possible to test site wiring fault indicators on some UPS's.

Other important UPS characteristics that are not part of the formal specifications can also be checked using Agilent ac sources. Such characteristics include the folowing:

- sensitivity to line voltage disturbances
- the stability and speed of phase-locked loops used in the internal design
- UPS response to:
  various ac line impedances (Agilent ac sources have programmable output impedance),

  surges of any magnitude (within the rating of the ac source) and duration,

  sags of any magnitude and duration,

  any number of line cycle dropouts,

  any part of a line cycle dropout

The phase at which the surge, sag, or cycle dropout occurs is completely programmable with Agilent ac sources, so the effect on the UPS output of *where,* with respect to phase, the disturbance begins can be investigated. Agilent ac sources can also act as arbitrary waveform generators so that the user can define the output waveshape in order to test UPS sensitivity to distorted input voltage waveforms.

Some specific applications utilizing Agilent ac sources to test UPS's are discussed in the following sections.

Voltage transfer points

Evaluating the UPS low and high voltage transfer points is easily accomplished by simply programming the ac source output up or down in steps while monitoring the UPS for the transfer to or from battery power. The Dual Power Analyzer option can help with this measurement by providing an external voltage measurement channel to measure the UPS output voltage, eliminating the need for a voltmeter on the UPS output. If there is a load on the UPS output, detecting the voltage transfer points can be accomplished by simply monitoring information available from the ac source. For example, when the transfer to battery power takes place, a significant decrease in ac source output current can be detected by reading back the ac source output current (UPS input current) at each voltage step. Figure 2 shows an example of a plot of UPS output voltage versus UPS input voltage obtained by stepping the ac source output voltage (UPS input voltage) first up, then down, through the UPS transfer points. Note the hysteresis around the transfer points. It is possible for the UPS to oscillate between ranges if the hysteresis is not designed properly. This is because the line impedance of the ac mains can dramatically influence the behavior of the UPS as a result of the voltage drop on the line impedance. The voltage drop varies with ac line current, and directly affects UPS input voltage. Since the transfer points are determined by the input voltage, as the UPS switches to or from battery power (resulting in decreasing or increasing ac line current) based on small input voltage changes, the input voltage changes even more due to voltage drop on the line impedance. Exploring the effects of line impedance on the behavior of the UPS is simplified with Agilent ac sources that have programmable output impedance settings. The output impedance on these sources can be set in the range of 0 to 1 ohm, in series with 20 µH to 1 mH.

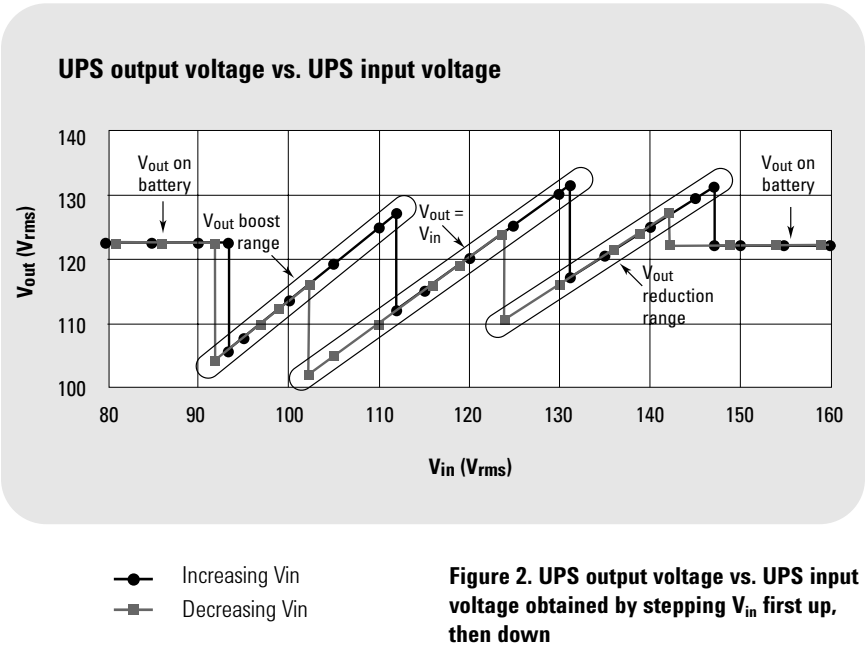
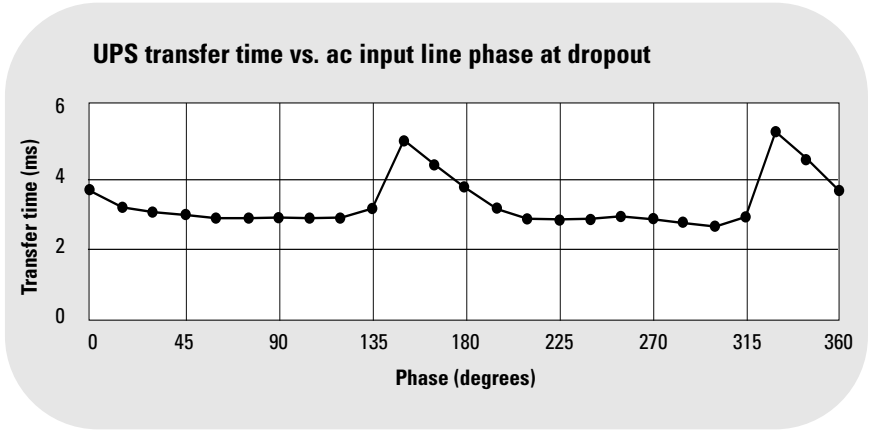


Figure 2. UPS output voltage vs. UPS input voltage obtained by stepping V_{in} first up, then down

Transfer time



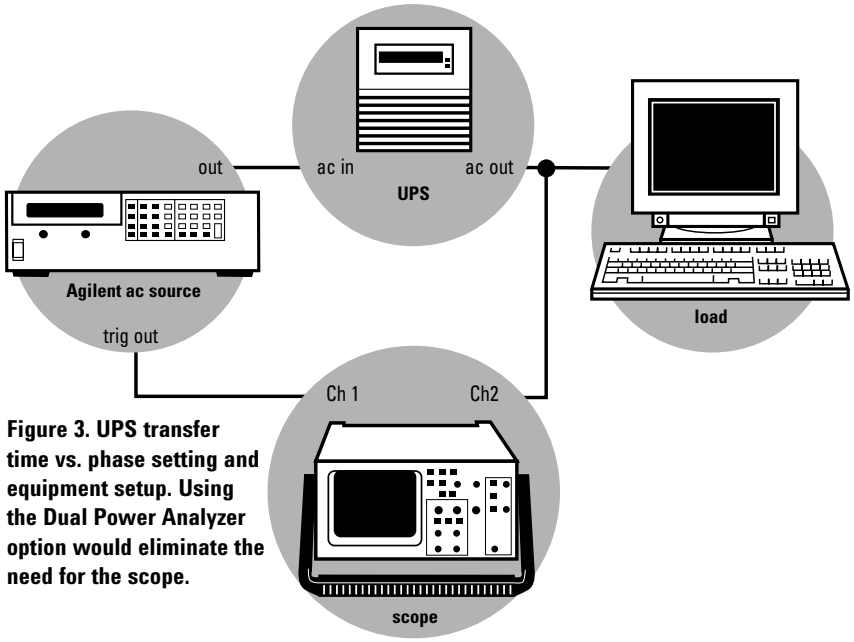


Figure 3. UPS transfer time vs. phase setting and equipment setup. Using the Dual Power Analyzer option would eliminate the need for the scope.

The programmable phase feature of Agilent ac sources allows for exploring the effect of the start of the outage on specifications like UPS transfer time. Figure 3 shows how the transfer time of a typical UPS varies with phase setting of the outage. Note the connection of the trigger output of the Agilent ac source in the figure. This trigger output signal can be configured to be precisely synchronized with the very beginning of the ac source output voltage outage making it easy to trigger the scope to signify the start of the transfer time measurement. Another aspect of UPS transfer time that can be explored using Agilent ac sources is the minimum outage that will cause the UPS to transfer power to its battery. Since Agilent ac sources can be configured to drop out any number of full or partial line cycles, the stimulus for this test is easy to set up. The scope in Figure 3 can be eliminated by using the Dual Power Analyzer option to monitor the output voltage of the UPS in place of the scope. (Refer to a more detailed description of this configuration later in this product note.)

Simulate generator output voltage variations

UPS products are sometimes powered from generators, perhaps due to a blackout where a backup generator takes over supplying the power in a building. Generators are notorious for producing output voltages with varying frequency, especially when the loading on the generator is varying. The UPS response to this varying input frequency is critical because, depending on the UPS design, it is possible that the UPS will continually go to battery power while attempting to synchronize itself with the input voltage waveform. Of course, this may unnecessarily drain the battery of critical reserve power.

Agilent ac sources can easily produce varying frequency waveforms simulating frequency jitter or frequency slewing to test the response of the UPS to these types of input power. The simplest way to produce varying frequency waveforms on the output of Agilent ac sources is to use the built-in frequency modulation commands available on sources that have the Dual Power Analyzer option. These commands allow control over the modulating frequency of the ac source output frequency and the magnitude of the frequency deviation.

With or without the option, another way in which varying frequency waveforms can be produced using Agilent ac sources is by using the LIST feature. This feature allows the user to define a list of ac source output parameters that can then be executed, step-by-step, paced by dwell times entered in the list by the user. The ac source itself can control the execution of the list

without computer intervention. Parameters that can be controlled include output voltage, frequency, waveshape, voltage slew rate, frequency slew rate, and phase. For example, the first step in the list can be for the output voltage to be 120 Vac at 60 Hz for 5 seconds. Step 2 keeps all parameters constant except the frequency changes to 65 Hz at a rate of 10 Hz/second for 0.5 seconds.

Step 3 could be for the voltage to change to 115 Vac at a rate of 10 V/second and the frequency to change to 57 Hz instantly. Once the list is defined, it is then possible to execute the list once, have the steps repeated a particular number of times, or repeat the list indefinitely.

Phase-locked loop speed and stability

Some UPS internal circuit designs use a phase-locked loop (PLL) synchronized with the ac input voltage in order to accurately produce the UPS output voltage. Using the Dual Power Analyzer option in conjunction with the Agilent ac source Graphical User Interface (GUI) software (available free from Agilent), the phase difference between the UPS input voltage and UPS output voltage can be easily evaluated. Additionally, evaluation of the speed and stability of the PLL can be facilitated using the ac source in conjunction with a period-to-voltage (P/V) converter and an oscilloscope. Figure 4 shows the configuration for this test. The ac source provides an accurate and instantaneous step change in frequency at the input to the PLL. With the output of the PLL connected to the input of the P/V converter, the output voltage of the P/V converter represents the period (or 1/frequency) of the PLL. With the stable frequency step change produced by the ac source at the input to the PLL, a perfect PLL would produce a simple voltage step change at the output of the P/V converter. However, the PLL is unable to track its input frequency perfectly. Therefore, the actual response of the PLL can then be explored on the scope by evaluating the speed at which the PLL responds, along with any overshoot and ringing that may occur in the response indicating the effective stability of the PLL design.

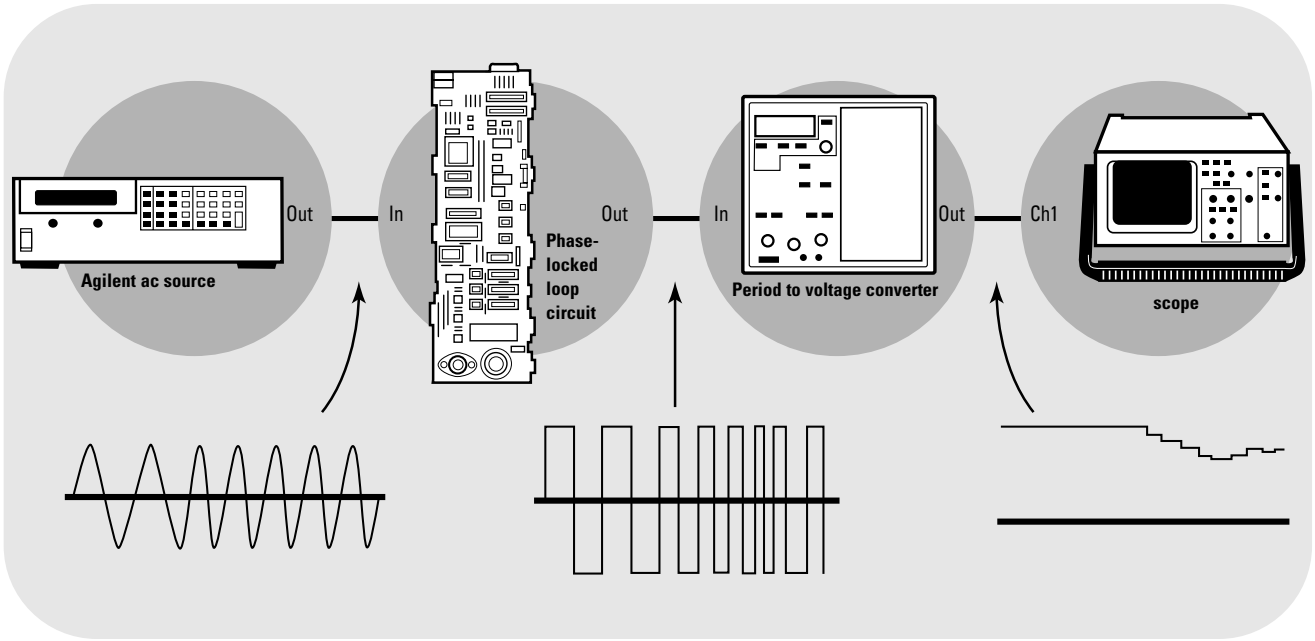


Figure 4. Phase-locked loop response test setup

More ac source features useful for testing UPS's

Agilent ac sources have many other features to help test UPS's, especially using automatic test equipment in a manufacturing environment. Remote sense capability allows the UPS to be located far from the output of the ac source, yet the source's output voltage will still be regulated right at the input of the UPS for accurate input measurements.

When applying power to a newly manufactured UPS for the first time, it is sometimes necessary to slowly increase the UPS's ac input voltage while monitoring its input current draw to ensure that there is no problem with the assembly of the UPS. Agilent ac sources have several features to help protect the input of the UPS should there be a severe fault condition in the UPS that would draw excessive input current.

Programmable rms current limit and programmable peak current limit settings can be used to limit the current, or the ac source output voltage slew rate can be programmed to a slowly rising value in conjunction with the rms current setting to ensure protection. As a last resort for protection of the UPS, it may be desirable to have the ability to quickly remove ac input power. For example, the ac source has a remote inhibit feature that can be connected to an emergency shut-off switch. When the switch is activated producing a short across the remote inhibit input terminals of the ac source, the ac source output will quickly become disabled, meaning output power will be removed within about 15 ms from the time the switch is closed.

Dual Power Analyzer option adds even more capability

The Dual Power Analyzer option is intended to expand the testing capabilities of the Agilent ac sources to further simplify UPS testing, as already noted several times. This option provides a measurement input channel for measuring an external voltage, and a measurement input channel for measuring an external current through a current shunt (included with the option).

Available on the Dual Power Analyzer channels are all of the standard Agilent ac source measurements such as: rms voltage and current, peak current, frequency, real power, reactive power, apparent power, and power factor. In addition, measurement commands have been added to specifically address UPS testing, including commands that enable the calculation of UPS transfer time, and phase difference between the UPS input and output voltage.

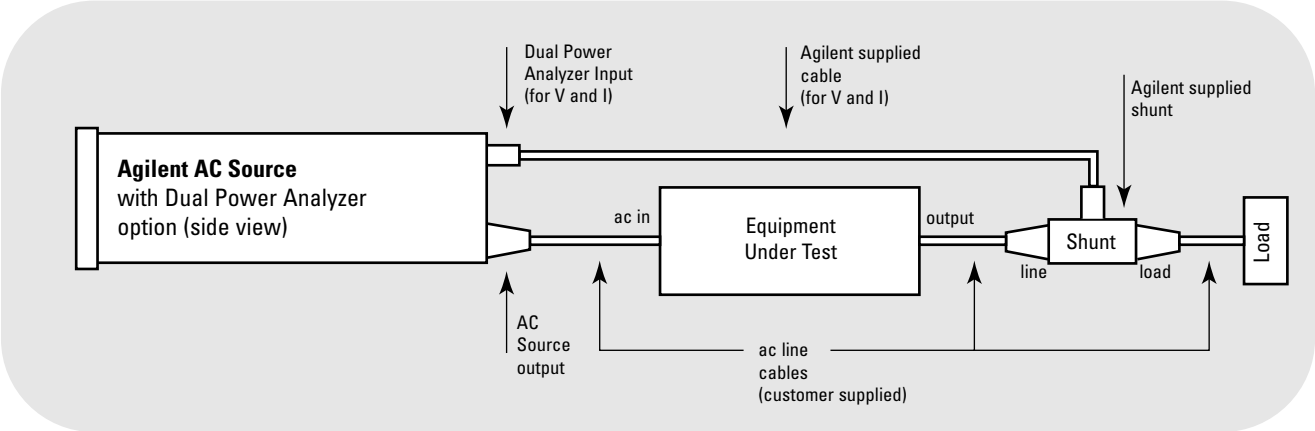


Figure 5. UPS test configuration using Agilent ac source with Dual Power Analyzer option

Peak voltage can be measured directly. Figure 5 shows the typical UPS test setup. Using this option, external measurement instruments like oscilloscopes, voltmeters, and power meters can be eliminated.

A simple example utilizing the extra measurement capability of the Dual Power Analyzer option is the measurement of efficiency of the UPS. The ac source provides the input power to the UPS, and all Agilent ac sources can measure their real power output, which is the UPS input power. The Dual Power Analyzer inputs on the option allow for the measurement of the real power of the UPS output. Simply dividing the UPS output power by the UPS input power yields the UPS efficiency.

To highlight the more advanced features of the Dual Power Analyzer option, consider the measurement of transfer time. Transfer time is the time it takes for the UPS ac output to switch to battery power once the UPS ac input voltage goes outside a predefined range. In order to measure transfer time, a more precise definition is necessary. For example, the UPS ac input can go from some nominal voltage (that is supplying power to the UPS output) to zero volts, which clearly would be outside the predefined range. This event would signal the start of the transfer time measurement. Detection of when the transfer is complete could then be defined as the time at which the absolute value of the UPS output voltage exceeds a predefined threshold level following the ac input voltage drop.

The Graphical User Interface (GUI) software package for Agilent ac sources uses this exact definition. The GUI provides easy access to many of the ac source capabilities, including those that are useful for testing UPS's. Figure 6 shows a sample screen-shot of the Agilent ac source GUI for an ac source with the Dual Power Analyzer option. All Agilent ac sources are constantly digitizing their output voltage and current waveforms in order to provide their extensive measurement capabilities. The Dual Power Analyzer option is also constantly digitizing its voltage and current input channels. The GUI can read all of this digitized data back from the ac source to the computer in order to display it on the computer screen, as shown in Figure 6. The upper waveform in this figure is the input voltage to a typical UPS, where the ac source output has been configured to drop to zero volts for 50 ms. The lower waveform is the UPS output voltage response to the input dropout. From these two waveforms, transfer time can be measured.

Figure 7 shows the transfer time test window, showing the parameters used to set up this test, along with the test result. From this figure, it can be seen that the transfer time measurement was 5.35 ms when the UPS experienced a 50 ms input voltage dropout to zero volts beginning at the peak of the line

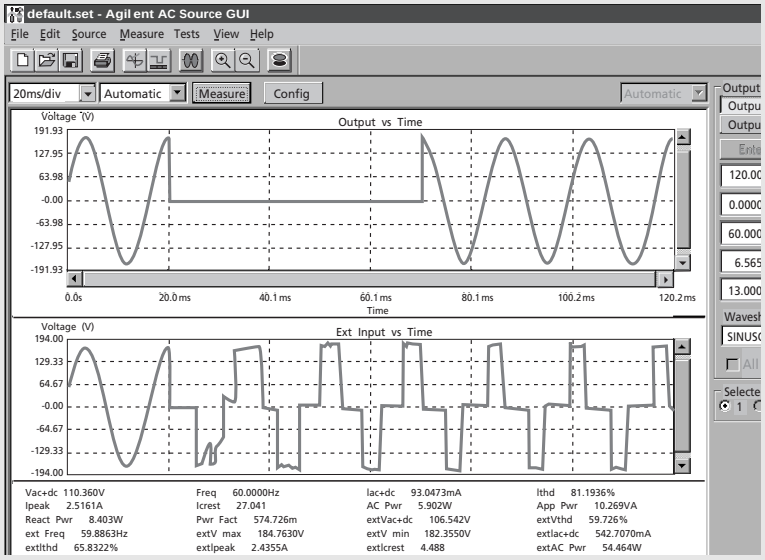


Figure 6. GUI screen-shot of waveforms using Agilent ac source with Dual Power Analyzer option. Top waveform is ac source output voltage (UPS input voltage). Bottom waveform is UPS output voltage. Note that all measured waveform data shown here is read directly from the ac source; no external instruments are used to read data.

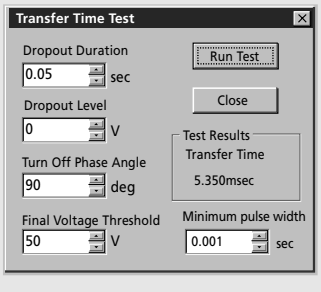


Figure 7. Transfer Time Test Window

(90 degrees). As specified in the test window parameters, this transfer was considered complete when the absolute value of the UPS output voltage reached the threshold of 50 V and remained above that threshold for at least 1 ms, the specified minimum pulse width.

Complete UPS testing involves a broad range of input voltages, input frequencies, and input waveshapes. Verifying proper UPS design and assembly includes subjecting the UPS to these ac input voltage disturbances while monitoring the UPS response. Agilent ac sources have the versatility to easily produce these needed input stimuli, and, with the Dual Power Analyzer option, to monitor the UPS response, ensuring that the UPS is operating properly.

Ordering Information

For Further Information visit our Agilent AC Power Products website at:
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