APPLICATION NOTE #108

Simulating Complex AC Power Line Disturbances Using the HGA Controller

Contents

1. Introduction

AC power line disturbances can not always be characterized by simple equations. Sometimes, phenomena are so elusive that they have to be captured in order to be analyzed. Once captured, it would be advantageous to be able to reproduce them to determine the effect of these disturbances on your equipment. By utilizing the capability of the HGA to generate arbitrary waveforms, this concept is very feasible. Using an ordinary digital storage oscilloscope and specific software, waveforms can be captured for reproduction through the HGA. Other sources of waveforms are available as well, for example a spreadsheet program can be used to formulate a special type waveform. Captured waveforms can be further refined by adding in events such as surges, sags or random noise. Due to the high horizontal and vertical resolution of the HGA controller, precise AC waveform events can be created and played back at programmable amplitude and frequency.

Waveforms can be stored in non volatile memory and assigned to one of three phase outputs. The program on the PC can acccess an infinite number of waveforms from a library that resides on the PC's hard disk.

While it would be possible to program these 18 waveform registers one data point at a time through the IEEE-488 bus or RS232C interface, it is much easier to use a program that accepts waveform data from various sources and downloads them to the HGA registers.
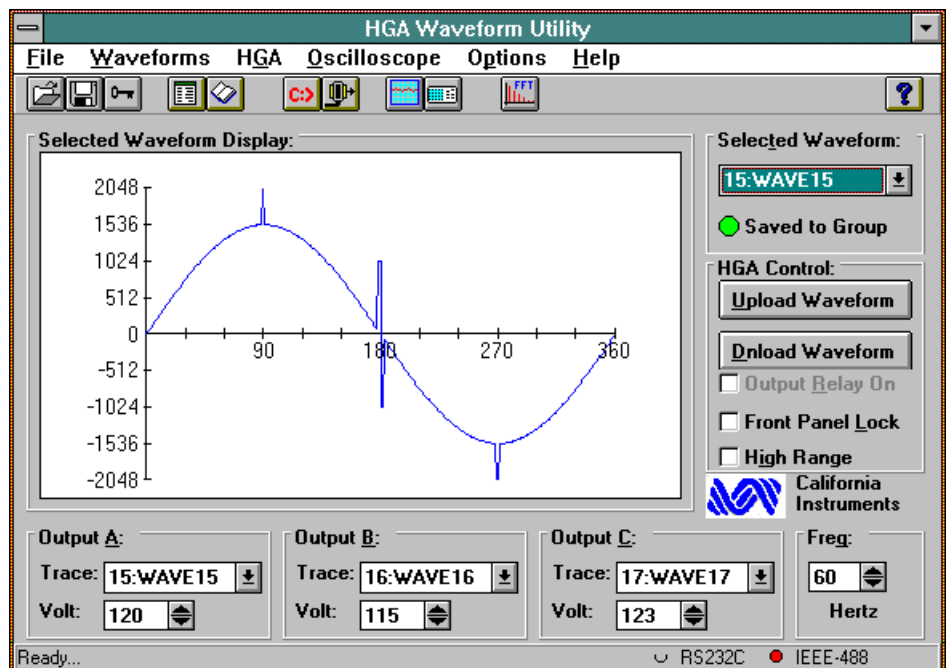
2. Defining Arbitrary Waveforms

The HGA controller consists of three fully independent arbitrary waveform generators - one for each phase of a three phase system - that are synchronized to a single timebase. Each arbitrary waveform generator is capable of producing 4096 data points of 12 bits each. This ensures both high horizontal (time) and vertical (amplitude) resolution.

Figure 1 : HGA Waveform utility software window

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The HGA Waveform utility software was developed for this purpose. This windows based program acts as a supplement to the HGA GUI software which is delivered with the HGA. It accepts waveform data from spreadsheets, digital storage oscilloscopes or its built in library of standard waveforms and delivers the information to the HGA's non-volatile waveform memories.

The same program also provides controls for setting the frequency and amplitude, controlling the output relay and communicating to the HGA directly from a command line. Both RS232C and IEEE-488 interfaces are supported.

3. Capturing Actual Waveforms

Since a storage oscilloscope has the ability to digitize and save waveform data, this data can be transferred to the HGA for repetitive playback at various frequency and amplitude settings. At the same time, the harmonic content of the signal can be measured using the HGA's analysis capabilities. The HGA utility program connects to a digital storage oscilloscope using the IEEE-488 bus and transfers waveform data from channel 1 to the PC. There, the data is converted to fit the record length of the HGA. This process usually requires compression or interpolation of the oscilloscope data as its record length invariably differs from that of the HGA. The converted data is displayed for review on the PC screen and, if acceptable, can be saved to disk. The waveform data thus obtained can be downloaded to the HGA at any time.

Unusual occurrences such as voltage spikes and transitions that cause havoc with electrical equipment can be captured and their effects on the equipment analyzed thoroughly by exactly reproducing the offending event repeatedly.

Some care is required in setting up the storage scope for this purpose as it needs to capture a single period of the event. For 60 Hz signals, this may require a variable timebase to obtain 1.666 ms/div or 16.66 ms/screen. Most modern storage scopes offer this capability. The scope used for the example shown here is an HP54601B, four channel, 100 MHz unit. Since only the waveform shape is required, the timebase and attenuators can be uncalibrated.

Figure 2 shows an example of an AC powerline disturbance captured on the oscilloscope. This is the actual output of the L Series amplifier after the signal has

Figure 2 : Power line disturbance captured on HP54601B scope
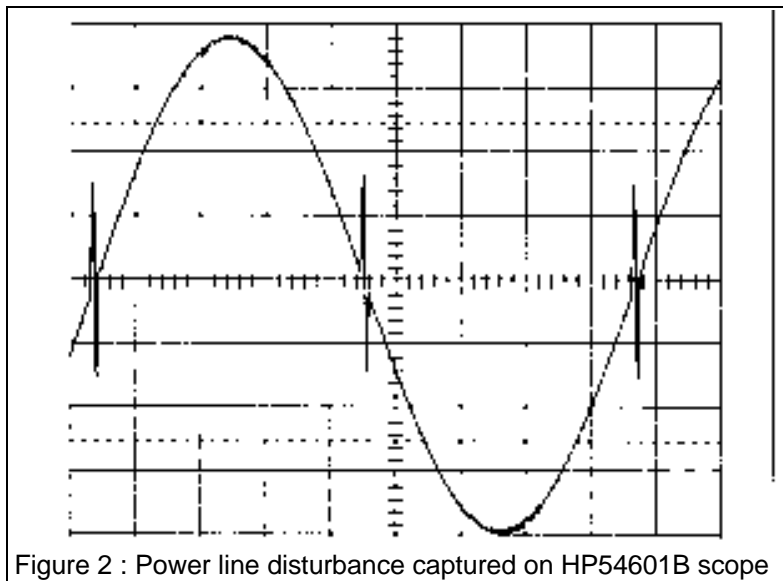
been downloaded to the HGA under PC control. The output is displayed on the same oscilloscope and plotted to a pen plotter.

Libraries of actual waveforms can be created on disk for later use. If the oscilloscope used has sophisticated trigger capabilities, rare power line disturbances can be captured using the single shot mode and reproduced through the HGA controller and AC amplifier for analysis and test purposes.

4. Synthesizing Waveforms Using Spreadsheets

Some types of waveforms are more readily described using a formula. A spreadsheet is an obvious choice for this purpose as it contains an arsenal of trigonometric functions. This provides both simple waveforms such as sine, triangle and square waves as well as complex combinations of primitive functions such as an amplitude modulated waveforms or a high frequency damped sinewave

Figure 2 : Mathematically created waveform, amplifier output
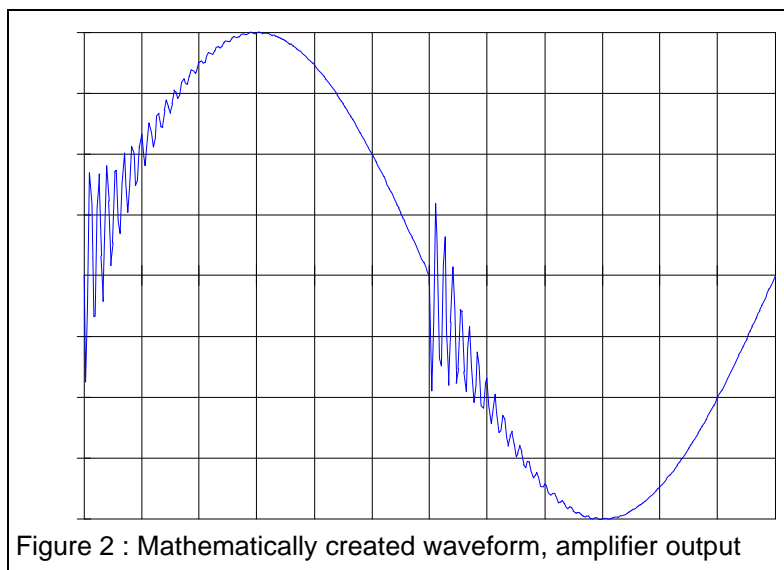
superimposed on a 60 Hz AC signal. Waveform data produced with a spreadsheet can be saved in a Comma Separated Value file format which can be read directly by the HGA waveform utility software. From there it is downloaded to the HGA for reproduction at variable amplitude and frequency on one or three phases.

Figure 3 shows an example of a waveform synthesized with an Excel spreadsheet. In this case, a 3 KHz exponentially damped sinewave is modulated on a regular AC sinewave.

5. Library Functions

In addition to being able to import waveforms from a digital storage scope or spreadsheet program, the HGA waveform manipulation program offers a built in library of functions. Figure 4 shows a picture of the library screen. Some of these functions such as Sine and Triangle provide simple waveforms that can act as the basis for creating more complicated events. Other functions such as clipped sine and noisy sine modify the standard sine wave.

The Goto function allows glitches to be positioned anywhere on the waveform at widths between 1° and 12°. These glitches can reach from +100% of peak voltage to -100 % of peak voltage. An example will illustrate the practical implications of this feature.

Assume we want to simulate overvoltage spikes occurring at a 90° phase angle. The required overvoltage should reach 11 % over the nominal peak value. We start out with a Sine wave at 90% of

Figure 5 : Single overvoltage disturbance

We can easily expand on this by adding a opposite spike at 91° and 271° as shown in figure 6. Spikes like this going in either direction can be added to any waveform, including actual signals captured with a digital storage scope. Waveforms shown in the current waveform display window can be copied to the Windows clipboard and pasted into a word processor for documentation purposes.

6. Three Phase Disturbances

The previous concept can be used in three phase applications where simultaneous disturbances on all three phases need to be simulated. By positioning power spikes 120° apart on each phase they will occur at the same moment in time on the output. The power spikes on each phase can be set to different levels as each phase operates from an independent arbitrary waveform generator. The amplifier output plotted from a storage scope is shown in figure 7.

7. Editing Waveform Data

To allow for detailed waveform editing, the HGA utility software also provides a data point editor that enables the user to change individual data points. The editor window is shown in figure 8. Data points are scaled between -2048 and +2047 to fully utilize the 12 bit resolution of the HGA's Digital to Analog converter. This corresponds to a 83 mV resolution on a 120 Vrms signal or 159 mV resolution on a 230 Vrms signal. Time resolution is about 0.088 degrees.
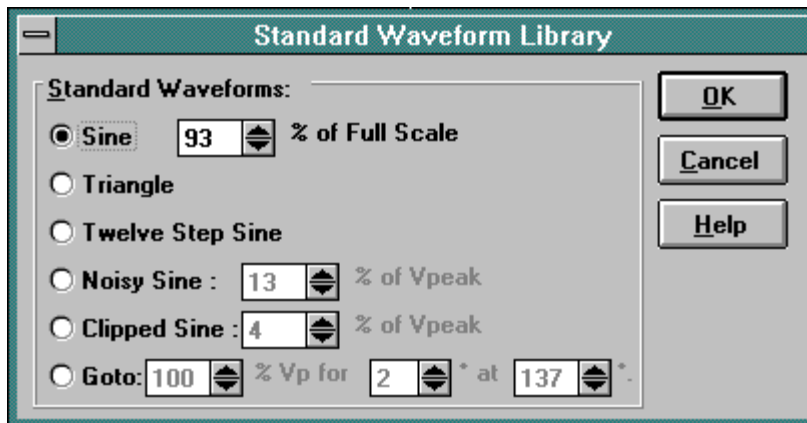

Figure 3 : Program library window

full peak to allow for the overvoltage spike. To that we add a spike that reached 100 % at 90° with a width of 1°. We also need to add a negative spike (-100%) at 270° of the same width. This requires that we invoke the Goto function twice. The end result in shown in figure 5.

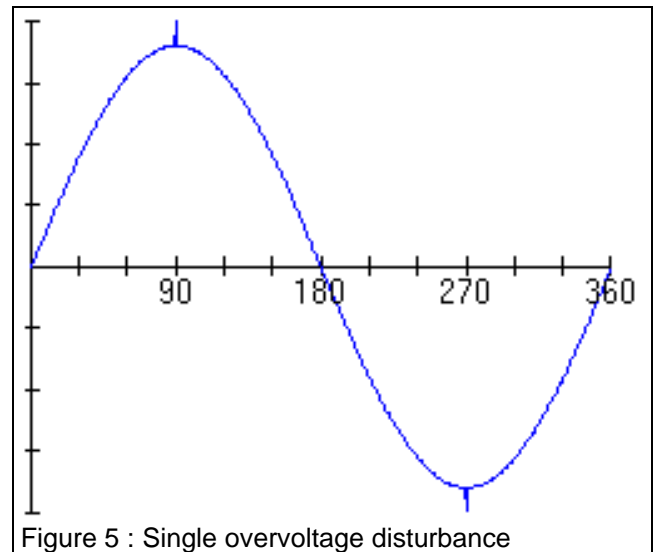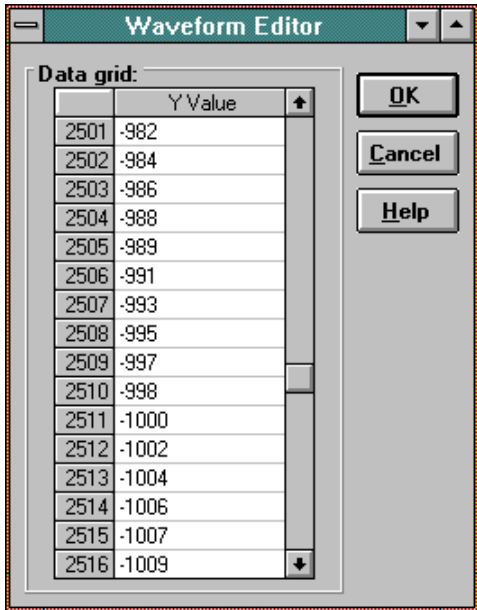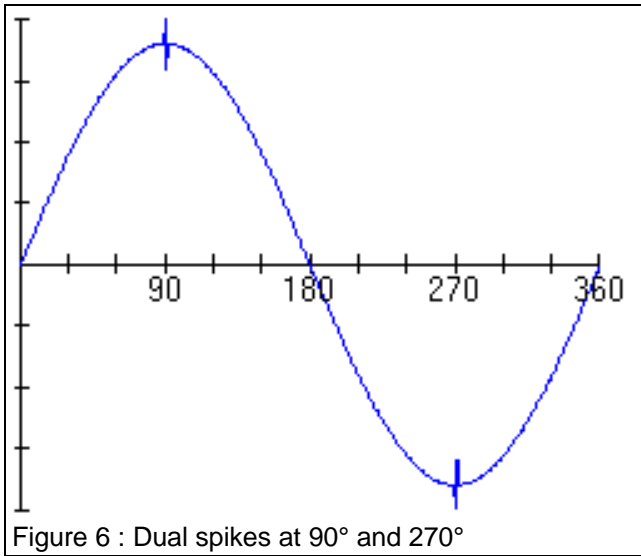Figure 6 : Dual spikes at 90° and 270°

Figure 8 : Waveform edit window

8. Summary

The HGA controller offers capabilities that extend beyond harmonic waveforms only. Harnessing the power of the three arbitrary waveform generators by using the ready to run HGA waveform manipulator software along with a high bandwidth AC power amplifier, such as the L or T Series, allows complex power line disturbances to be simulated with ease.

9. Requirements

The applications described in this application note require an L or T Series AC power amplifier and HGA controller as well as a PC capable of running Windows 3.1™. The HGA can be connected through the RS232C interface or the IEEE-488 bus if the PC is equipped with an IEEE-488 controller card. The HGA waveform manipulator software is available free of charge and requires 2 Mbytes of hard disk space. Call California Instruments to request your free copy.
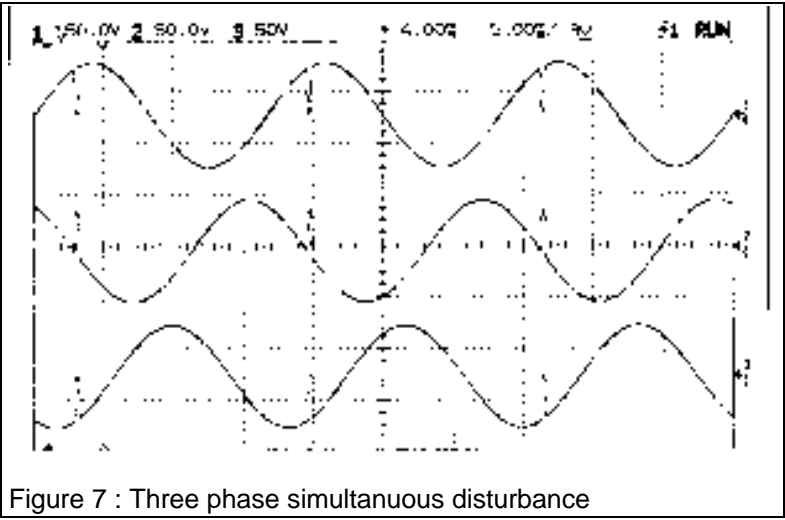

Figure 7 : Three phase simultanuous disturbance

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