

Purpose

The purpose of this application note is to demonstrate how to simulate the phase shift that may be encountered on an AC line when power is applied from a second, “synchronized” source of AC Power. While the power lines are generally locked in frequency, phase shifting can often occur. Shown below are methods used to create a phase shift using Pacific’s UPC-Series Programmable Controller. The goal is to create a sub-cycle offset that can be programmed to occur at any phase angle on the fundamental waveform, and last for a specified number of degrees.

Pacific Power Source’s UPC-Series Controller can create both time-based and cycle-based transients. Transients consist of a series of 1 to 100 distinct steps (or segments) that modify the steady-state output of the power source. Each segment makes a linear change in voltage, frequency and/or waveform in the time specified. Transient timing is stated in seconds; either 0 for cycle based transients, or programmed transitions ranging from 0.0002 to 300 seconds. Refer to the UPC-Series Operators Manual for more detail on steady-state and transient-programming features.

Whether to use time-based, cycle-based or waveform substitution depends on the complexity of the transient and the desired results following the end of the event. In this case, waveform creation and substitution can be used, but the effort in creating many waveforms of exacting precision was unnecessary. Additionally, when creating a discontinuous transient using waveform substitution, further disruption of the AC Power applied to the equipment under test would occur when the transient ended.

Instead of substituting a custom waveform on a cycle for cycle basis, the following examples make changes to the output voltage using time-based transients. Once created and stored in Pacific Power’s UPC Controller, the demonstrated waveform will occur every time a “Transient” is triggered on the UPC.

This application note is divided into two parts: Part I, Leading Phase Angles for simulating a positive phase shift; and, Part II, Lagging Phase Angles for creating an apparent phase shift in the opposite direction. Transient graphics with UPC output sequences follow each example to help demonstrate output results and UPC programming.

More Application, Information, and Pricing available at:

The TestWorld logo, featuring a stylized globe icon to the left of the word "TestWorld" in a bold, sans-serif font.

250 Technology Way
Rocklin, CA 95765

sales@testworld.com
1-855-200-TEST (8378)

Click to go www.TestWorld.com

Part 1 – Leading Phase Angles

Transient Calculations

To accomplish this test, full use of the minimum programmable time increment (0.0002) along with the ability to change frequency (waveform clock speed) within a transient provided the simplest solution. Calculating the waveform consists of three transient segments (steps):

Segment 1	Determining the starting phase angle (S)
Segment 2	Adding the desired phase shift
Segment 3	Restoring the waveform or returning to the desired steady-state frequency.

Step 1 Determine the time of starting phase Angle (T_S)

The time of the starting phase angle (T_S) defines where on the waveform the phase shift is to begin. This will be the duration of the first transient segment where no changes to the steady state output are desired. The starting time for the phase angle is determined by the formula:

$$T_S = (S/360^\circ) * (1/\text{Hz.})$$

Where : S = the desired starting phase angle
Hz. = The fundamental frequency

Step 2 Add the desired phase shift (P)

The desired phase shift is the number of degrees that the waveform will be shifted relative to the preceding portion of the waveform. In this case, we use the 0.0002 minimum segment timing to cause the waveform to change as quickly as possible (maximum clock speed). Note that while the calculations are all performed in seconds, the end result is stated in Hertz to be programmed into the UPC.

Desired phase shift (P) is Calculated:

$$(360^\circ/P) * (0.0002) = F_s$$

$$1/F_s = \text{HZt.}$$

Where: P = the desired Phase shift in degrees

F_s = the time of the necessary frequency in seconds

HZt. = the calculated transient frequency value

0.0002 = maximum clock speed

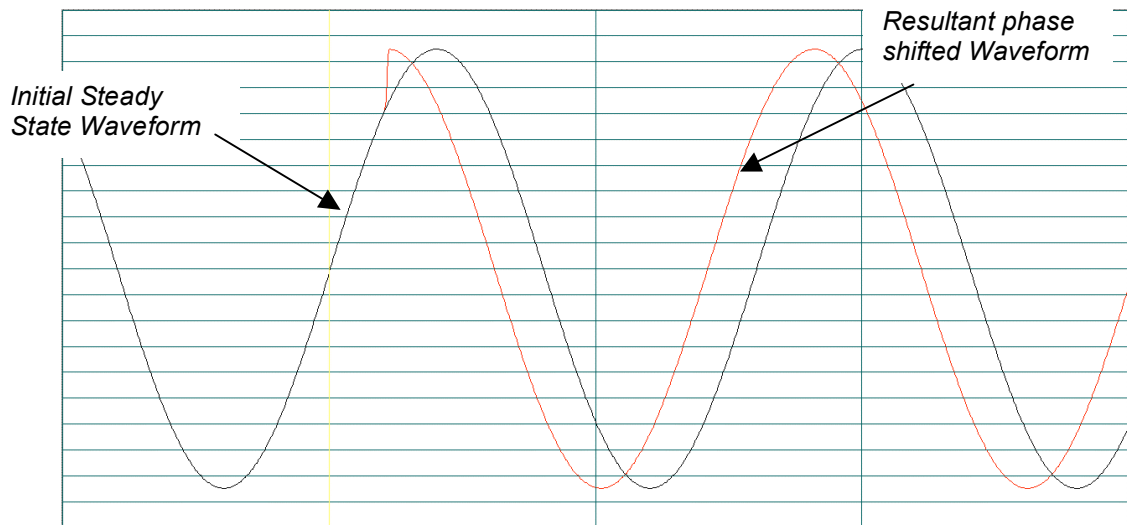
Step 3 Restore the waveform to the normal steady-state frequency

This final transient segment simply returns the unit from the maximum clock speed back to the normal (fundamental) output frequency (Hz).

Exampled Waveforms

Note: In the following examples, 50Hz. (0.020 seconds/cycle) was used to simplify the calculations.

Example 1 - Output waveform with 45° phase shift at 45°



1. Determine the time to the starting phase angle.

$$(S/360^\circ) * (1/\text{Hz.})$$

Where : S= the desired starting phase angle
 Hz.= The fundamental frequency

$$(45/360) * (1/50) = 0 * 0.020$$

$$T_s = 0.0025$$

2. Add the desired phase shift (P)

$$(360^\circ/P) * (0.0002) = F_s$$

$$1/F_s = \text{HZt.}$$

Where: F_s = the time of the necessary frequency in seconds
 HZt. = the calculated transient frequency value

$$(360^\circ/45^\circ) * (0.0002) = 0.0016$$

$$1/0.0016 = 625\text{Hz.}$$

3. Restore waveform to normal steady state frequency.

UPC Output Sequence, Output waveform with 45° phase shift at 45°**Program 86 Steady State**

Phase	Volts	Waveform	Degrees
A	120.000000	1	0

Form: 1
Frequency: 50.00
Transient Events: 1
Coupling: DIRECT
Current Limit: 40.000 Amps

Transient Segment 1

Phase	Volts	Waveform
A	120.000000	1

Frequency: 50.00
Time: 0.002500 Seconds

Transient Segment 2

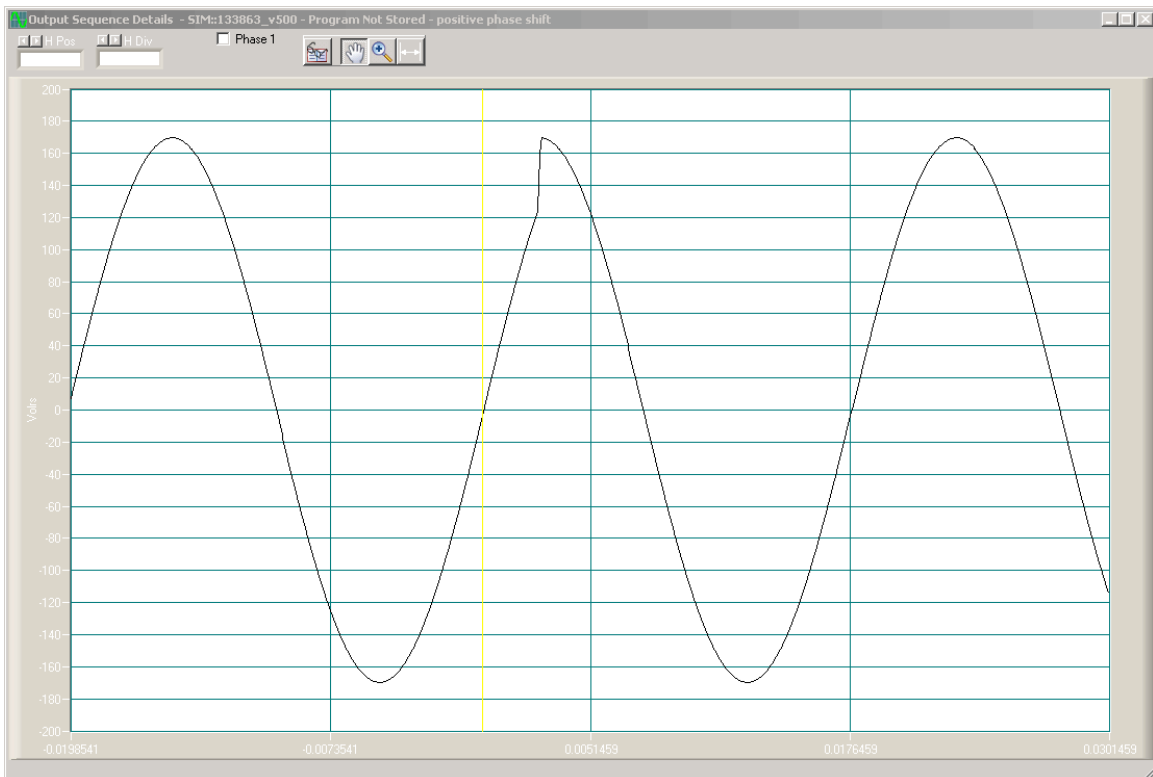
Phase	Volts	Waveform
A	120.000000	1

Frequency: 625.00
Time: 0.000200 Seconds

Transient Segment 3

Phase	Volts	Waveform
A	120.000000	1

Frequency: 50.00
Time: 0.000200 Seconds



Application Note

Simulating The Effects of a Transfer Switch By Creating Phase Shift Transients

Part 2 – Lagging Phase Angles

Transient Calculations

Lagging phase angles are similar to the leading phase angle discussed in Part 1, except in this case, an equivalent voltage level (V_e) for the specified lagging phase angle (AI) must be determined. The UPC's ability to simultaneously change the output voltage and frequency permits programming the output to begin lagging at a specified phase angle, dwell for the desired period and resume normal operation at the steady state voltage and frequency. Calculating a lagging waveform requires four transient segments (steps):

- | | |
|-----------|--|
| Segment 1 | Determine the time starting phase angle (T_S). |
| Segment 2 | Slowing down the UPC clock and determining the equivalent RMS voltage (V_e) at the specified lagging phase angle (AI). |
| Segment 3 | Calculate the dwell time for the desired phase shift (P) and return the voltage back to the nominal slope (amplitude) over the delay period. |
| Segment 4 | Return the waveform to the steady state voltage and frequency. |

Step 1 Determine the time to the starting phase Angle (T_S)

The time of the starting phase angle (T_S) defines where on the waveform the phase shift is to begin. This will be the duration of the first transient segment where no changes to the steady state output are desired. The starting time for the phase angle is determined by the formula:

$$T_S = (S/360^\circ) * (1/\text{Hz.})$$

Where : S = the desired starting phase angle
 Hz. = The fundamental frequency

Step 2 Slow the UPC Clock and calculate the equivalent output voltage (V_e) at the lagging angle (AI).

The UPC Clock is slowed by programming the frequency to its lowest value.

The equivalent output voltage is the rms level that the nominal waveform attains at the specified lagging phase angle. This is calculated by taking the sine of the target phase angle and multiplying it by the nominal output voltage.

Equivalent Output Voltage (V_e) is calculated by:

$$\text{Sine}(AI) * \text{Nominal Output VAC}_{\text{rms}} = V_e$$

Step 3 Add the desired phase shift (*P*) by determining Dwell Time (*D*)

The desired phase shift is the number of degrees that the waveform will be shifted relative to the preceding portion of the waveform. Based on the fundamental output frequency, the amount of desired phase shift must be programmed as a delay (dwell). The voltage is then returned back to the nominal slope (amplitude) over the delay period.

Dwell time is the time in seconds that occurs over the specified phase shift (*P*):

$$(1/\text{HZ}) / 360^\circ = \text{seconds/degree}$$

$$(\text{Seconds/degree}) * P = D$$

In this step, the waveform is also programmed back to the nominal output voltage level over the calculated dwell time.

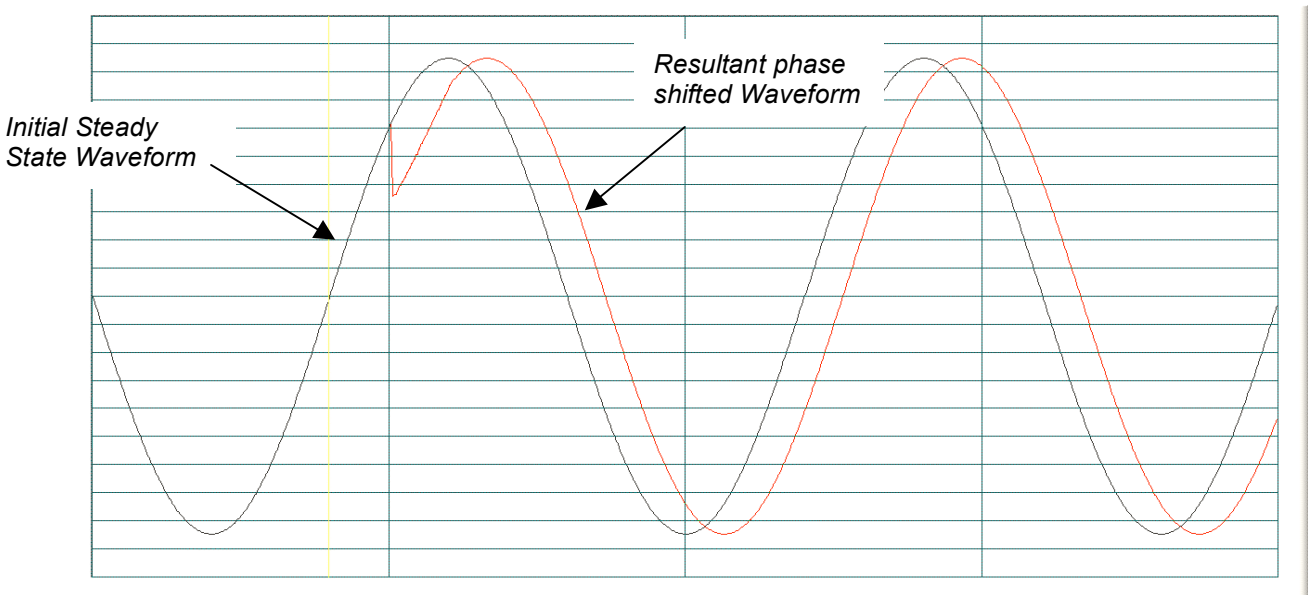
Step 4 Restore the waveform to the normal steady state frequency

This final transient segment simply returns the unit from the minimum clock speed back to the normal (fundamental) output frequency (Hz).

Example Waveforms

Note: In the following example, 50Hz. (0.020 seconds/cycle) was used to simplify the calculations.

Example 1 - Output transient where at 45° on the fundamental waveform, output voltage lags back to the 35° point and injects a 45° phase shift.



1. Determine the starting phase angle.
 $(S/360^\circ) * (1/\text{Hz.})$
 Where : S = the desired starting phase angle
 Hz. = The fundamental frequency

$$(45/360) * (1/50) = 0.125 * 0.020$$

$$T_s = 0.0025$$

2. Slow the UPC Clock and calculate the equivalent output voltage (V_e) at the lagging angle Al .

$$\text{Sine}(Al) * \text{Nominal Output VAC}_{\text{rms}} = V_e$$

Where: Al = the desired lagging Angle
 V_e = the equivalent output voltage at lagging angle

$$V_e = (\text{Sine}35^\circ) * 120\text{V} = 68.83$$

3. The desired phase shift (P) is added and Dwell Time (D) is determined

$$(1/\text{HZ}) / 360^\circ = \text{seconds/degree}$$
$$(\text{Seconds/degree}) * P = D$$

Where: P = the desired phase shift
 D = dwell time in seconds for transient time value

$$(1/50)/360 = 0.000055\text{s/deg.}$$
$$0.000055 * \underline{45^\circ} = 0.00247 \text{ seconds}$$

4. Restore waveform to normal steady state frequency.

Application Note

Simulating The Effects of a Transfer Switch By Creating Phase Shift Transients

UPC Output Sequence - Output transient where at 45° on the fundamental waveform, output voltage lags back to the 35° point and injects a 45° phase shift

Program 6 Steady State

Phase	Volts	Waveform	Degrees
A	120.000000	1	0

Form: 1
Coupling: DIRECT
Frequency: 50.00
Current Limit: 40.000 Amps
Transient Events: 1

Transient Segment 1

Phase	Volts	Waveform
A	120.000000	1

Frequency: 50.00
Time: 0.002500 Seconds

Transient Segment 2

Phase	Volts	Waveform
A	69.000000	1

Frequency: 20.00
Time: 0.000200 Seconds

Transient Segment 3

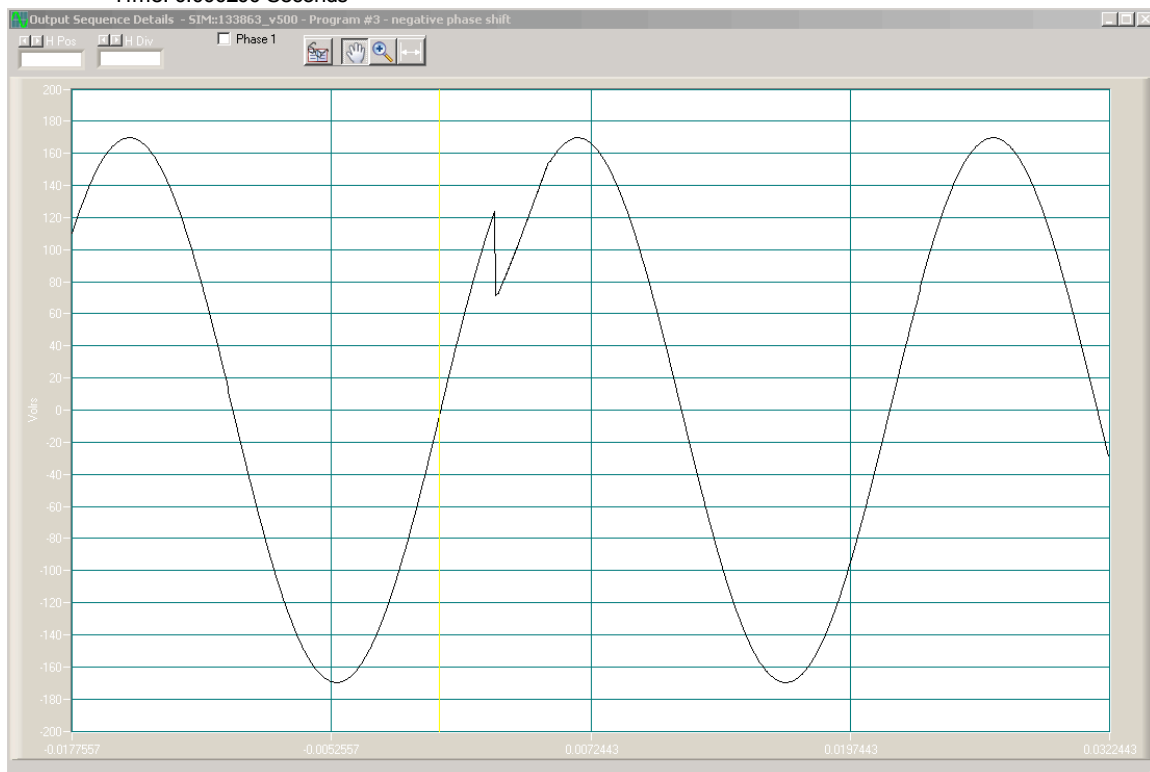
Phase	Volts	Waveform
A	120.000000	1

Frequency: 20.00
Time: 0.002500 Seconds

Transient Segment 4

Phase	Volts	Waveform
A	120.000000	1

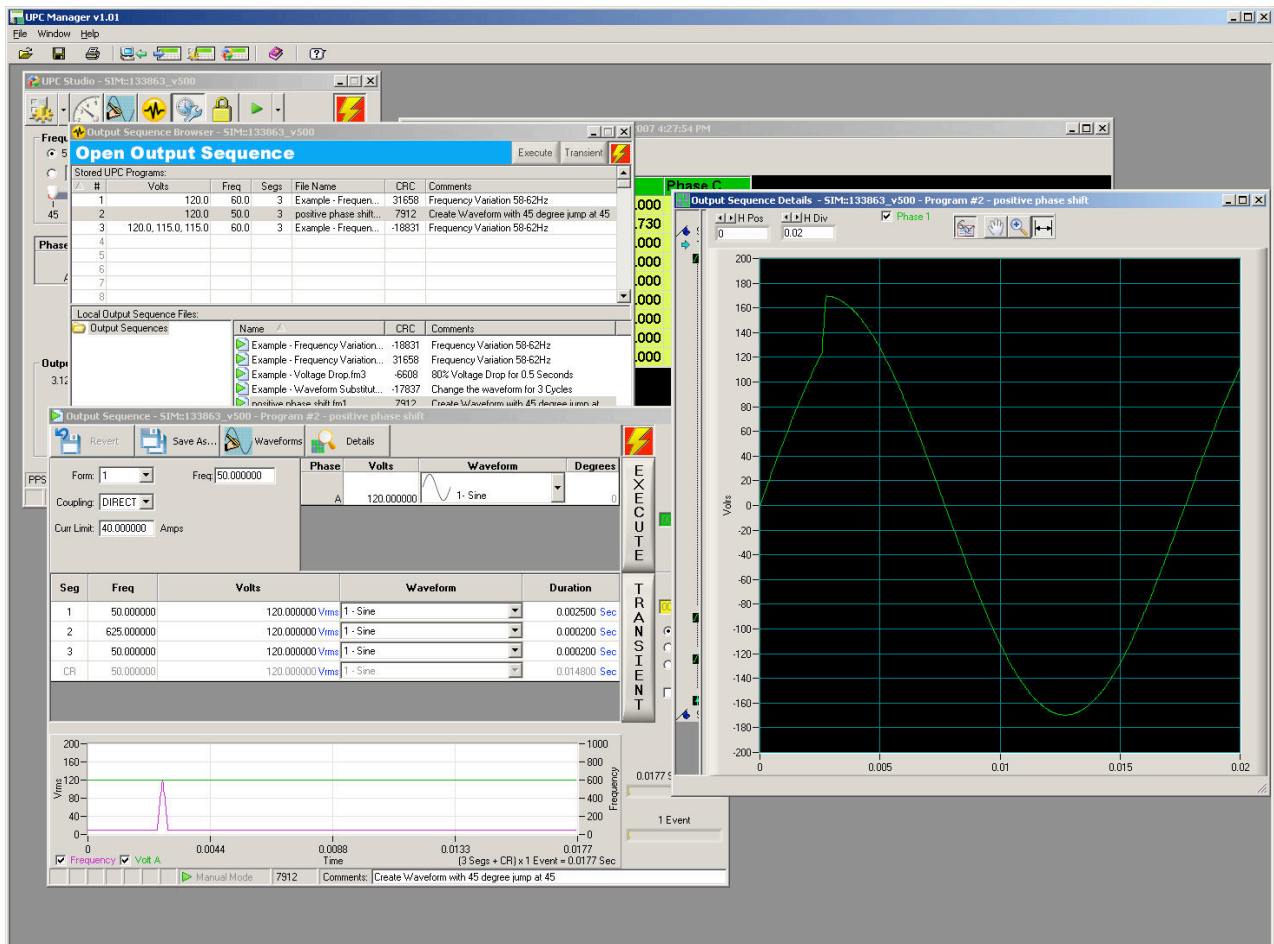
Frequency: 50.00
Time: 0.000200 Seconds



Simulating The Effects of a Transfer Switch By Creating Phase Shift Transients

When creating complex waveforms, transients and output sequences, Pacific's *UPC Studio Software* is an invaluable tool.

The graphic below is a screen capture of the UPC Studio software used to test and evaluate the results of the previous discussion including the Output Sequence Browser, Program 2 Output Sequence, and the Output Sequence Details view.



For further details on Pacific's UPC Studio or upgrade information please write or call: 800-854-2433 (USA only) or +1-949-251-1800, or email sales@pacificpower.com.