Pacific Power Source

Technical Memo

Programmable Output Impedance Option

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Introduction

Pacific Power Source's "Programmable Output Impedance" Option (Prog-Z) is available for use with the UPC-1/3 and UPC-12/32 Universal Programmable Controllers (UPC). The purpose of this option is to generate a "Synthetic Impedance" that may be used to simulate line losses typically found with high impedance distribution lines or high frequency power systems. An additional benefit of Prog-Z is the ability to compensate for line losses by programming a negative impedance in various test applications.

Theory of Operation

Prog-Z is a form of current compensation by which the output current signal sensed by the AMX or ASX-Series Power Source is added directly to the output oscillator signal. This summation acts at analog speeds to reduce (or in the case of positive impedance, increase or boost) the output voltage as the current is demanded by the load.

Refer to Figure 1. When Prog-Z is off, the UPC CPU sets both the output amplitude and waveshape (as programmed by the operator) by loading the appropriate data into the Amplitude and Waveform digital-to-analog converters. The output of the Waveform (WF) DAC then provides a low voltage, analog representation of the desired output to the appropriate Amplifier stage. The Power Amplifier then replicates the oscillator waveform and provides the voltage and current necessary to drive the equipment under test.

When Prog-Z is enabled, the operator specified impedance value is loaded into the Prog-Z DAC. Also provided to the DAC is an output current signal representative of the Power Source output. The resulting current waveform (as scaled by the value of the Prog-Z DAC) is then summed with the Waveform DAC to create the oscillator output. This waveform is then replicated by the power amplifier stage.

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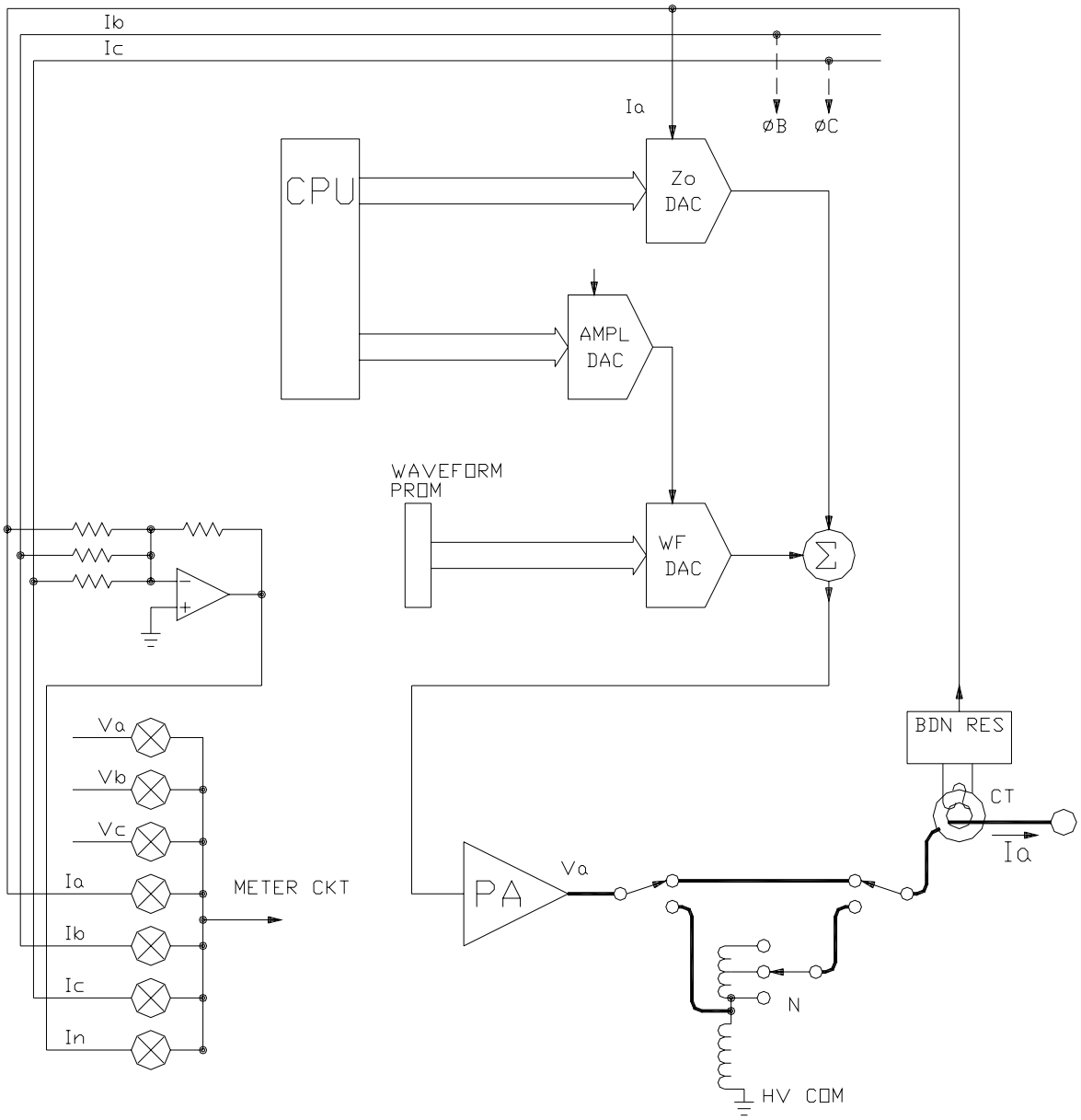

Figure 1 – Prog-Z Block Diagram

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Discussion

Combined with Pacific's Harmonic Synthesis and Transient Capabilities, Programmable Output Impedance is a very powerful tool when performing power line disturbance simulations. However, the method by which Prog-Z functions and its affect on the output waveform under different load conditions, must be carefully considered.

The graphs and tables on the following pages demonstrate the feature's effect on non-linear loads. Since the current waveform of a non-linear load is not sinusoidal, the effect of the feature is easily visualized. With the output voltage modified at analog speeds by the instantaneous peak current, calculated impedance values are not necessarily intuitive.

Prog-Z is best demonstrated with a purely resistive load, using Ohm's law. Reference Figure 2, with Prog-Z off, a 25 ohm resistive load (Rload) and a programmed output voltage (Vprog) of 125V, the system output voltage (Vout) will equal 125V. In this condition we could then expect 5Arms (Iload) to be delivered by the power amplifier.

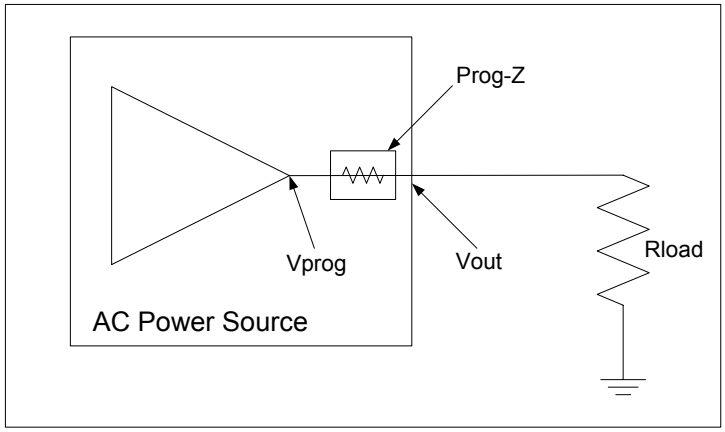

Figure 2 – Prog Z System View

Consider the same conditions stated above but with 1 ohm of Prog-Z programmed. A signal proportional to the 5Amps developed at the load is summed with Vprog. The resulting output voltage may be estimated as: Vout= Vprog-(Z*Iload) = 120V. With Vout equal to 120V and Rload = 25 ohms, Iload will reduce to 120V/25Ω or 4.8Arms.

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Example Impedance Results

The following graphs and tables demonstrate the results of Programmable Impedance on a non-linear load using a typical ASX-Series Power Source.

The first graph depicts the output voltage and current waveforms of a typical non-linear load with Prog-Z set to zero ohms. Of particular note is the peak current demand of 7.71Apk creating a 2.78:1 crest factor.

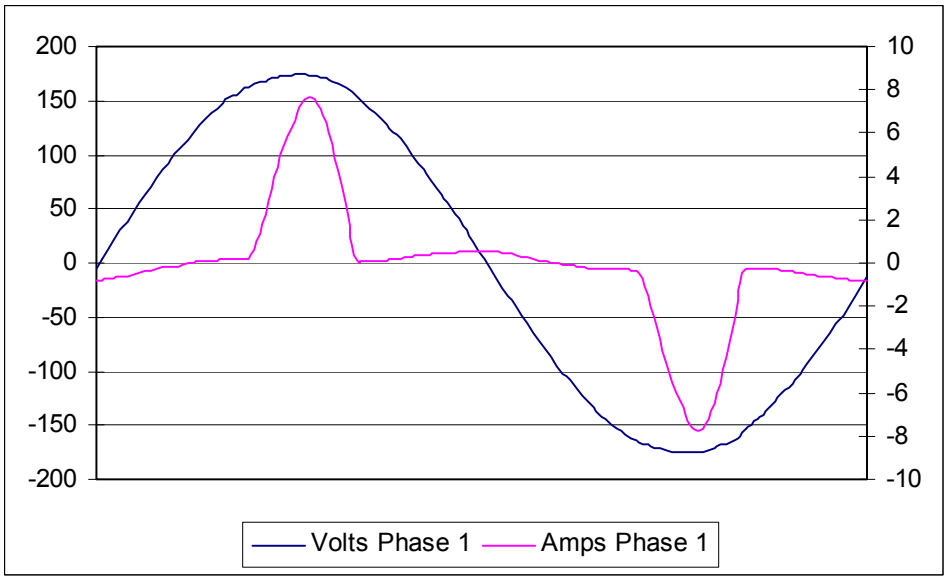

Figure 3 - Prog-Z = 0 Ohms

Prog-Z = 0 ohms	
Vrms	124.20
Irms	2.77
Ipeak	**7.71**
Icrest	2.78
KW	0.23
KVA	0.34
PF	0.66

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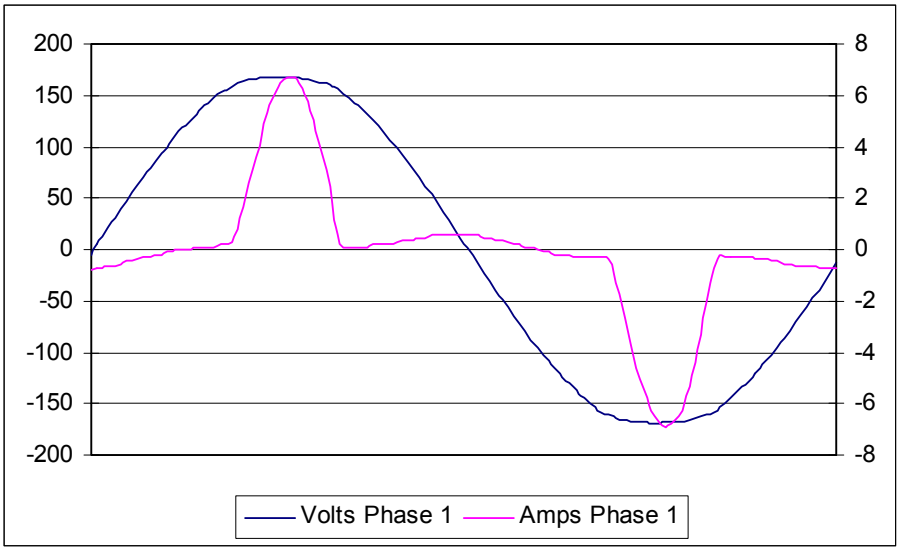
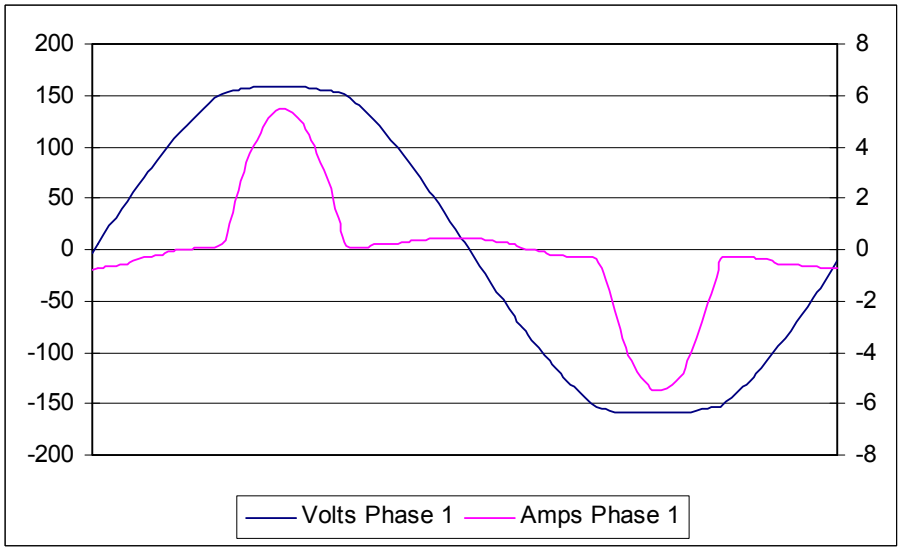
Using the same load, Figure 4 depicts the result of 1 ohm of output impedance. Here we see the results on the peak of the voltage waveform as the current is demanded by the load. This increased impedance served to reduce both the Peak current and the Current Crest Factor. Note the flat topping of the voltage waveform as the current term modifies Vout.



Prog-Z = 1 ohm	
Vrms	122.46
Irms	2.58
Ipeak	**6.70**
Icrest	2.59
KW	0.21
KVA	0.31
PF	0.68

Figure 4 - Prog Z = 1 Ohm

As an extreme example, 3 ohms of output impedance is programmed. Again, as the output voltage is reduced, the peak current and crest factor change accordingly.



Prog-Z = 3 ohms	
Vrms	119.2
Irms	2.29
Ipeak	**5.50**
Icrest	2.39
KW	.19
KVA	027
PF	0.71

Figure 5 - Prog Z = 3 Ohms

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A final graph demonstrates the affect of negative impedance. In this case the output current boost the output voltage at the same time the current increases. Negative impedance may be used to compensate for line losses that occur with external magnetics or other high impedance distribution lines.

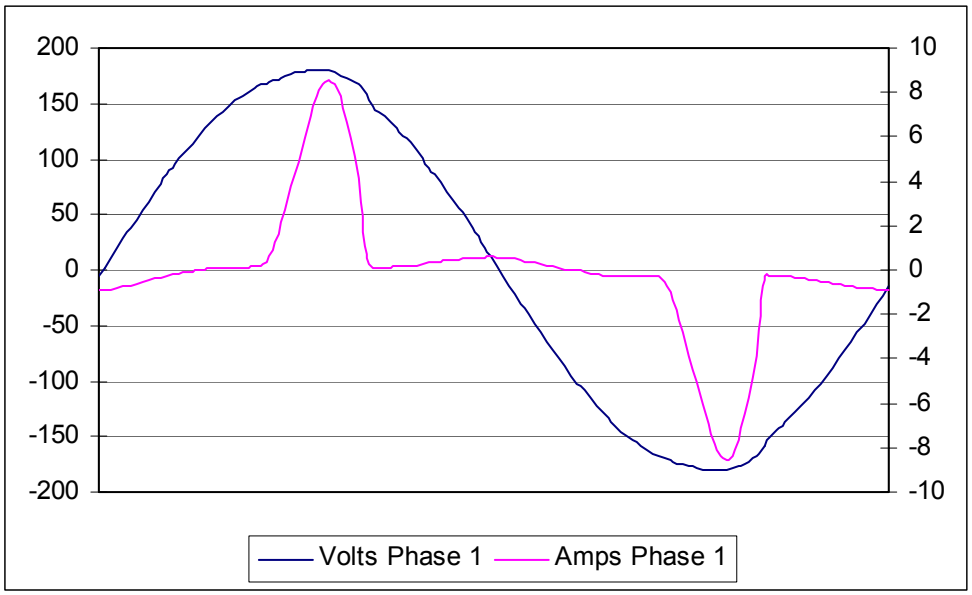

Figure 6 - Negative 1 Ohm

Prog-Z = -1 ohm						
Vrms	Irms	Ipeak	Icrest	KW	KVA	PF
126.20	2.95	**8.99**	3.04	0.24	0.37	0.65

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Notes and Conclusions

As previously stated, Prog-Z, Pacific's waveform editing and transient capabilities may be combined to form an extremely powerful Power Line Disturbance Test System. For common steady state or frequency conversion applications, Prog-Z along with Continuous Self Calibration (CSC) may be used to improve power source regulation into dynamic loads. The CSC function maintains a constant output voltage at the metering point by comparing the metered value with the programmed output voltage and automatically changing the power source output voltage. With CSC maintaining the "programmed to actual (metered)" output voltage accuracy (operating over several 100 milliseconds), Prog-Z may be used to compensate for fast or intermittent load changes that may occur as loads are switched onto the power grid.

Due to the "real time" nature of the feature, Programmable Output Impedance offers the following benefits:

1. Speed; sub-cycle response times to load induced current demands are accommodated.
2. Requires no additional hardware. While the option is normally specified at the time of order and factory installed, fielded units may be upgraded by the operator.
3. External AM and AUX IN inputs offered by the AMX and ASX Series Power Sources are summed with Prog-Z values.

As the purpose of Prog-Z is to modify the output voltage waveform, the following precautions should be noted:

1. Large values of Programmable Impedance may cause output voltage distortion to increase into linear loads as the voltage waveform begins to flatten out or clip.
2. Leading power factors may cause positive regulation and extreme cases may cause the power source output to become unstable.
3. In the three phase mode, only one Prog-Z value is provided. It is assumed that a balanced load is applied to the source and each phase is to be equally modified.