PACIFIC POWER SOURCE
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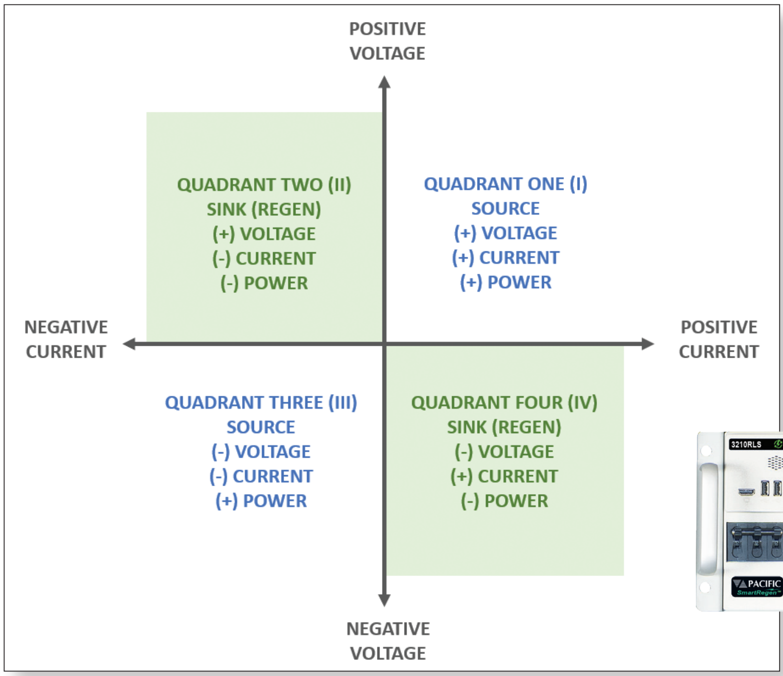
APPLICATION NOTE

RLS and ELZ Series 4-Quadrant AC & DC Load Operating Modes



Abstract

The Pacific Power Source RLS and ELZ Series Regenerative AC&DC electronic loads support several load operating modes not found on conventional dissipative AC or DC electronic loads. As regenerative loads that return most of the power to the utility, they are far more energy efficient than conventional electronic loads which convert absorbed energy from the unit under test into waste heat.

This application notes explains the various operating modes made possible by the 4 Quadrant capability of the RLS and ELZ Series loads and the extensive selection of operating modes and load settings available to the user. These load functions are also available as options on several bidirectional AC&DC power sources from Pacific Power.

Growing Bidirectional Test Requirements

A growing number of green energy products is permeating into many industries and product areas. This is true in both energy generation and distribution as well as transportation. Renewable wind and solar energy generation requires Wind and Solar inverters that connect to the power grid. These grid-connection products need testing during development, manufacturing and service. At the same time, the growing electrification of trains, buses, cars and even airplanes also involves a multitude of bidirectional electricity flow products and subsystems.

All these applications require bidirectional power test equipment for either AC, DC or both. Bi-directional AC and DC power source and electronic load combinations provides the necessary capabilities and flexibility engineers and test technicians need to function in these industries.

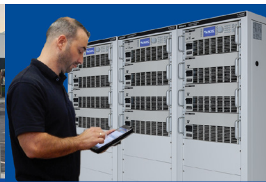
This application note focusses on applications requiring electronic load functions. One of the major advantages of bidirectional electronic loads like the RLS or ELZ is the energy efficiency attained by returning energy back to the power grid instead of converting this energy into heat and using HVAC systems to keep the test lab or production area cool. This represents a significant cost savings that can quickly recover the cost of the test equipment investment compared to traditional non-regenerative test setups.


FREQUENCY CONVERSION

AEROSPACE

MILITARY

RENEWABLE ENERGY

EV CHARGING

PRODUCTION TEST

Electronic Load Operating Modes

Most electronic loads offer a standard selection of operating modes as shown in the table below.

Operating Mode	*Abbreviation*
Constant Current	CC
Constant Power	CP
Constant Resistance	CR
Constant Voltage	CV

Of these, CC mode - Constant Current - is the most commonly used setting as it allows the amount of AC - or DC - current to be controlled by the user. CV Mode is less common as it is used primarily for current source development and test.

In the case of a DC load, setting the DC current level is the only available parameter setting. In case of an AC load, other parameters may be available as well such as crest factor and power factor. However, conventional non-regenerative AC Loads have limitations with respect to crest & power factor setting ranges. This is due to the inability of a dissipative AC Load to conduct current a zero volt. Since these load use FETs to dissipate the energy put into the load input, when the AC input voltage drops below the minimum voltage needed to operate the FET in linear mode, the current flow is interrupted for some period of time. This results in two important limitations:

1. The momentary loss of current flow around zero volt results in current distortion (cross over distortion).
2. It is not possible to shift the AC current with respect to the input voltage unless an non-linear crest factor type current waveform is used that has no current at the voltage zero crossings.

The consequence is that linear loads other than resistive cannot be simulated by conventional dissipative electronic loads. Figures 1 and Figure 2 below illustrate the difference.

Since a regenerative AC load does not have this limitation, the power factor and can be controlled easily by shifting the current with respect to the input voltage. This means combinations of R (Resistance), L (Inductive) and C (Capacitance) can be programmed by the user.

Electronic versus Regenerative AC Loads

An electronic AC load and a regenerative AC load are two types of instruments used to test and simulate the performance of power supplies and inverters. The main differences between the two are as follows:

Operation: An electronic AC load is a device that consumes energy from an AC power source, converting it into heat or other forms of energy. In contrast, a regenerative AC load can consume energy from the AC source, but can also return energy back to the source by operating in a bidirectional mode, acting as a power supply when needed.

Efficiency: Electronic AC loads convert the consumed energy into heat, which is a relatively inefficient process. Regenerative AC loads, on the other hand, can convert the consumed energy back into usable power, resulting in much higher efficiency.

Cost: Regenerative AC loads are generally more expensive than electronic AC loads, due to their more complex design and ability to return energy back to the power grid.

Applications: Electronic AC loads are typically used for testing power supplies and inverters under purely resistive or crest factor current load conditions. Regenerative AC loads are used in applications where power is generated from renewable energy sources or other sources that require bi-directional energy flow testing.

Control: Regenerative AC loads require more advanced control systems than electronic AC loads, as they need to be able to switch between absorbing and supplying power as required.

In summary, electronic AC loads are more suitable for testing of simple AC power supplies and inverters, especially at lower power, while regenerative AC loads are better suited for more complex testing of higher power sources that require bidirectional power flow.

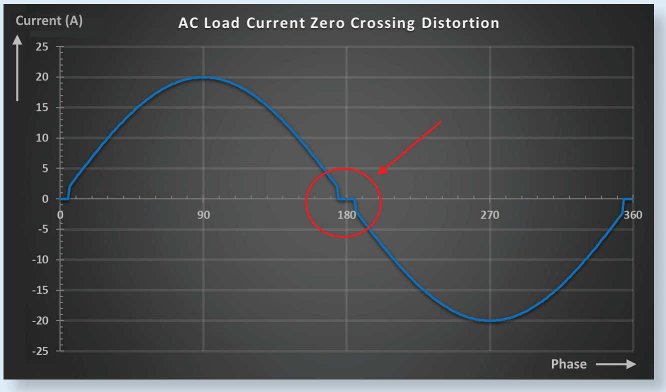


Figure 1: **Dissipative** AC Load Current

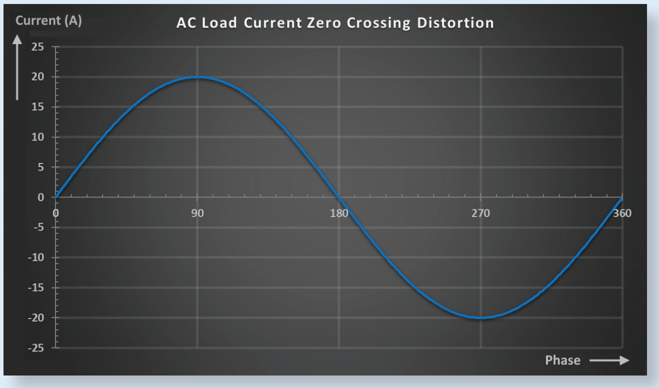


Figure 2: **Regenerative** AC Load Current

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CC Mode Operation

In CC mode, the current and phase angle with respect to the AC input voltage can both be set by the user. The current waveshape is also selectable as either sine or any arbitrary waveshape. An example of the ease of setting load conditions is shown in Figure 3. By setting the phase shift to zero degrees, voltage and current are in phase as is the case for a resistive load. This condition is shown in Figure 4 using the internal scope of the ELZ. Note the lack of current crossover distortion at zero volt.

Setting the phase angle to a leading or lagging phase angle will change the load condition to inductive or capacitive and change the apparent power and power factor. This condition is shown in Figure 5.

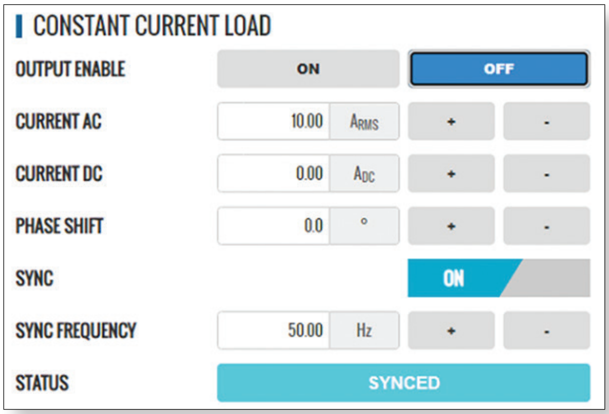

Figure 3: CC Mode Setting Example

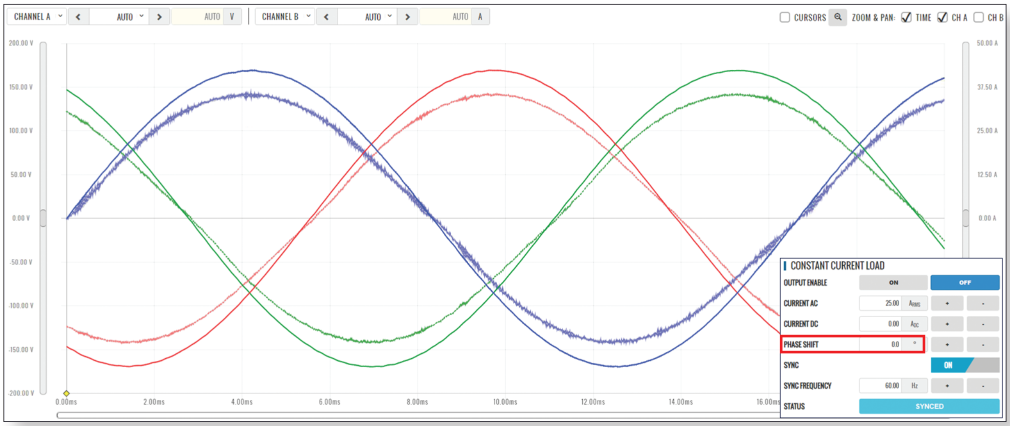

Figure 4: ELZ Load CC Mode, Zero Phase Shift Example

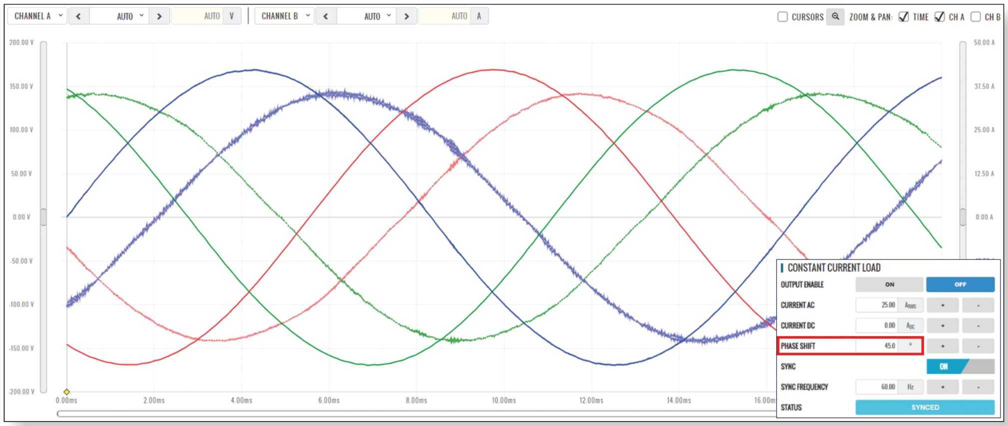

Figure 5: ELZ Load CC Mode, 45 Degree Phase Shift Example

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Constant Power & Resistance Modes

These two common load modes are derivatives of Constant Current mode but allow programming in either Power or Resistance respectively.

In both cases, the user's setting is converted by the load in the required current setting by using Ohm's law. This makes it easier to obtain the desired load operation as this calculation is dynamic so the current will adjust with the AC or DC input to conform with ohm's law. This is represented by the diagrams in Figures 6 and 7. While the inherent operation is the same as CC mode, programming is more intuitive for applications where the Power or Resistance needs to be simulated.

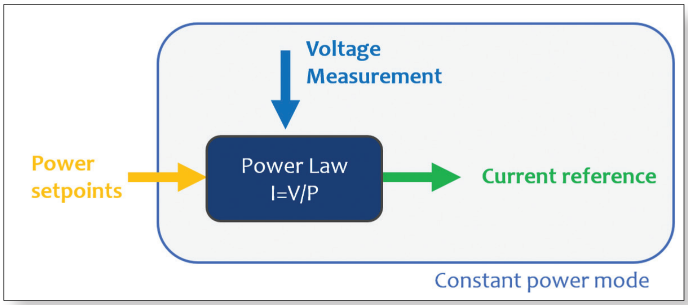

Figure 6: Load CP Mode Inputs to Current

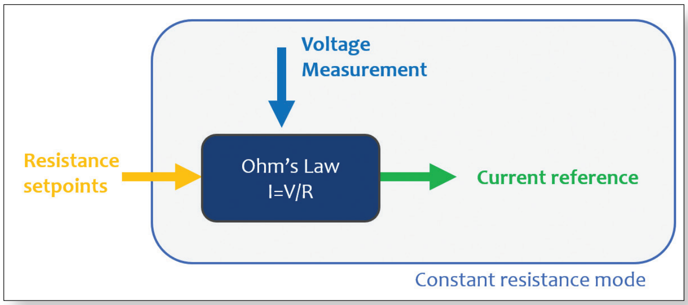

Figure 7: Load CR Mode Inputs to Current

Circuit Emulation Mode (ELZ Series Only)

Circuit Emulation (CE) mode is a proprietary load operating mode of the ELZ Series AC & DC Source/Load unit and builds on the Constant Current mode as well by allowing the user to select from a wide range of linear circuit topologies and set values for the various R, L and C parameters of each circuit.

Some example circuits are shown in Figure 8. These circuits emulate a wide range of commonly used power electronic circuits. For example, the anti-islanding LCR load test requirement for distributed generators like PV Inverters and Bidirectional V2G EV Charging products can be programmed on the ELZ. This eliminates the need for switchable L, R and C load banks to meet this requirement.

An LCR load can be simulated in CE mode using the "R // Series RL, Series RC" circuit setting. This circuit, depicted in Figure 9, allows the values of R, L and C including any series resistance for the L and C components to be programmed.

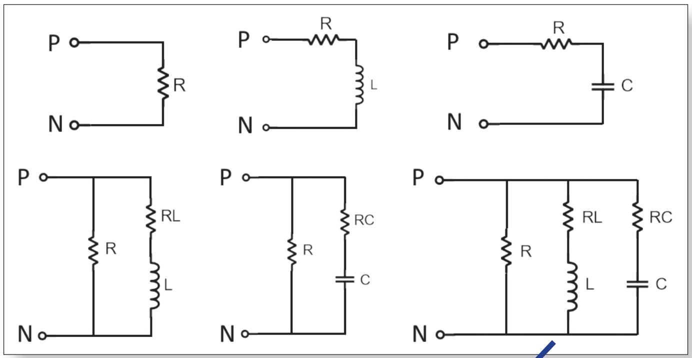

Figure 8: ELZ Load Linear Circuit Emulation Examples

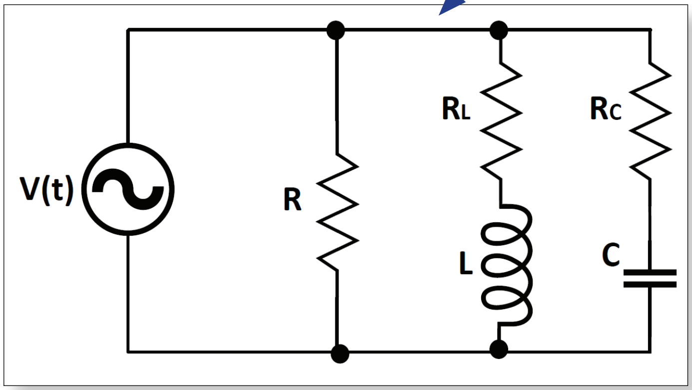

Figure 9: CE Mode R // Series RL, Series RC Circuit

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Non-Linear Rectifier Circuit Emulation

The Circuit Emulation load also supports two non-linear rectifier circuits. One is a single phase rectifier and the other a three phase rectifier. The typical high crest factor current resulting form single phase rectification is reflected in the load current when using this circuit. The same applies for the 3 phase rectifier circuit shown in Figure 9. The RL, L and C elements can be set to emulate a power factor correction scheme often used on AC input circuits. The R element can be used to increase or decrease the simulated load power as needed.

The two associated current waveshapes are shown in Figure 10 and 11. The actual current crest factor is also programmable of course. Settings for mode and individual R, L and C component values can be made from the front panel or using the web interface.

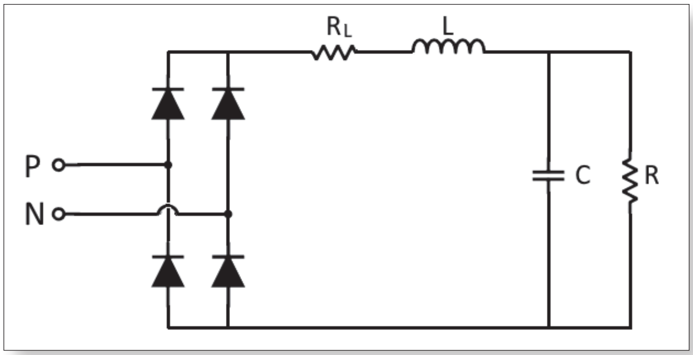

Figure 9: Singe Phase Rectifier Circuit Emulation Example

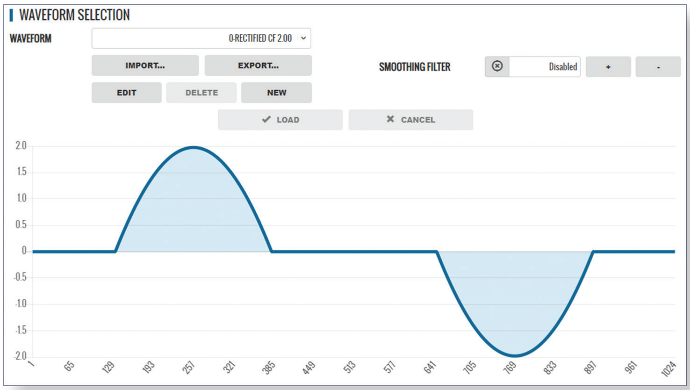

Figure 10: Single Phase AC Rectifier Current Waveform

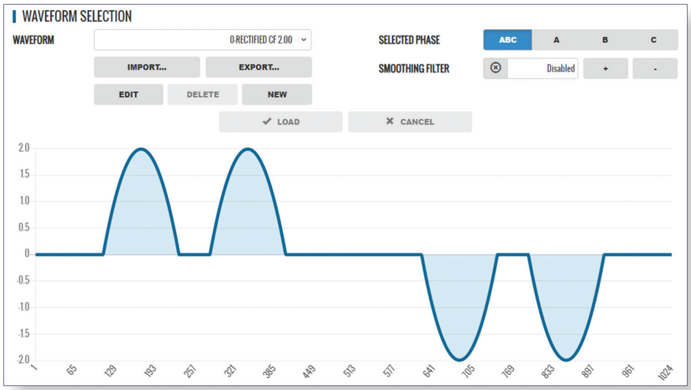

Figure 11: Three Phase AC Rectifier Current Waveform

The later is shown in Figure 12. The actual current waveform for single phase AC rectifier mode is shown in Figure 13. In this mode, the current is phase aligned with the voltage (zero phase shift) as is the case for a rectified AC waveform.

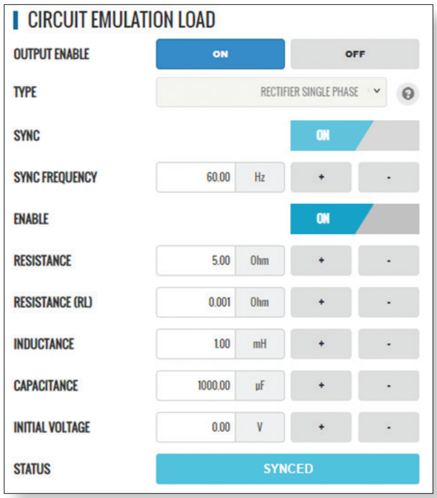

Figure 12: Actual Current waveform

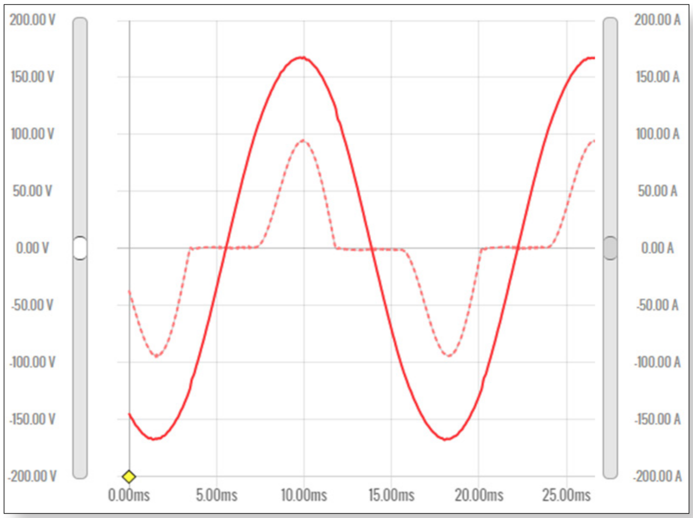

Figure 13: Actual Current waveform

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Special Load Functions

Beyond the load mode selections covered so far, these loads also include several special functions, some of which are covered in the next sections.

Inrush Current Simulation

This mode is used to similar AC inrush current behavior of power factor corrected loads that take several cycles to adjust the current waveshape to obtain high power factor operation. The first few cycles (programmable by the user) will exhibit a typical diode bridge rectified AC waveform until a certain power level is reached where the power factor correction circuits start to take over.

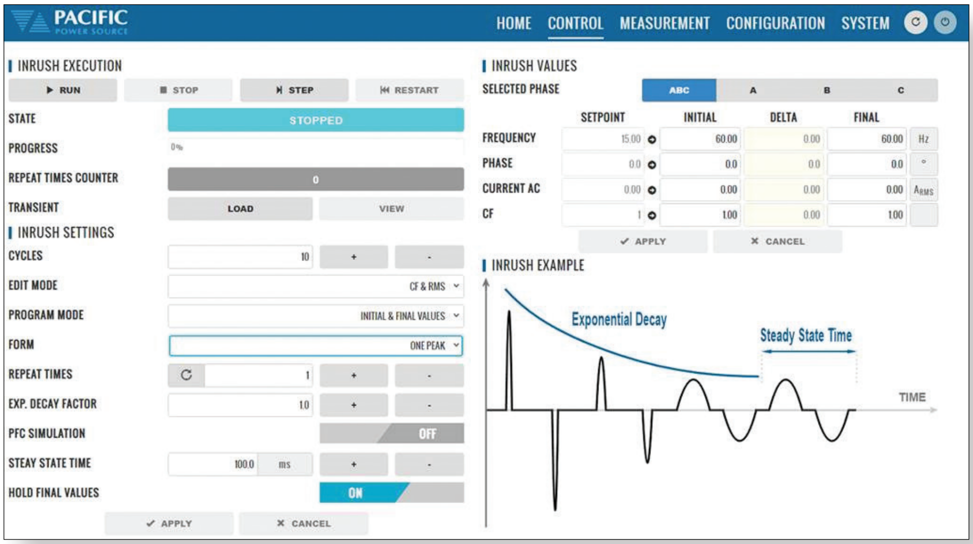

Figure 14: Inrush Current Simulation Setup Screen

The setup screen for the function as shown in Figure 14 allows full control of current levels, number of cycles, current waveform, repetitions, decay of peak current levels, PFC, Frequency and phase shift with respect to input voltage. The current inrush sequence consists of a decay section followed by a steady state section, the duration for each which can be programmed by the user.

Load Features By Operation Mode

The table below summarizes available load features by operating mode. The large number of operating modes and features allows a wide range of load conditions to be programmed by the user.

Feature	*CC Mode*	*CP Mode*	*CR Mode*	*CE Mode*
Sine or User Defined Waveform	✓	✓	✓	
AC Rectified Waveform	✓	✓	✓	✓
Current Harmonics & Inter harmonics	✓			
Sync Mode	✓	✓	✓	✓
Transient Programming (List, Step or Pulse)	✓	✓	✓	
AC Mode, DC Mode & AC+DC Mode	✓	✓	✓	✓
Analog Input Programming	✓	✓	✓	

Table 2: Available Features by Load Operating Mode

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Maximum Voltage & Current Limits

The RLS Series offers a single voltage range with maximum voltage and current limits for each of four quadrants as shown in Figure 15.

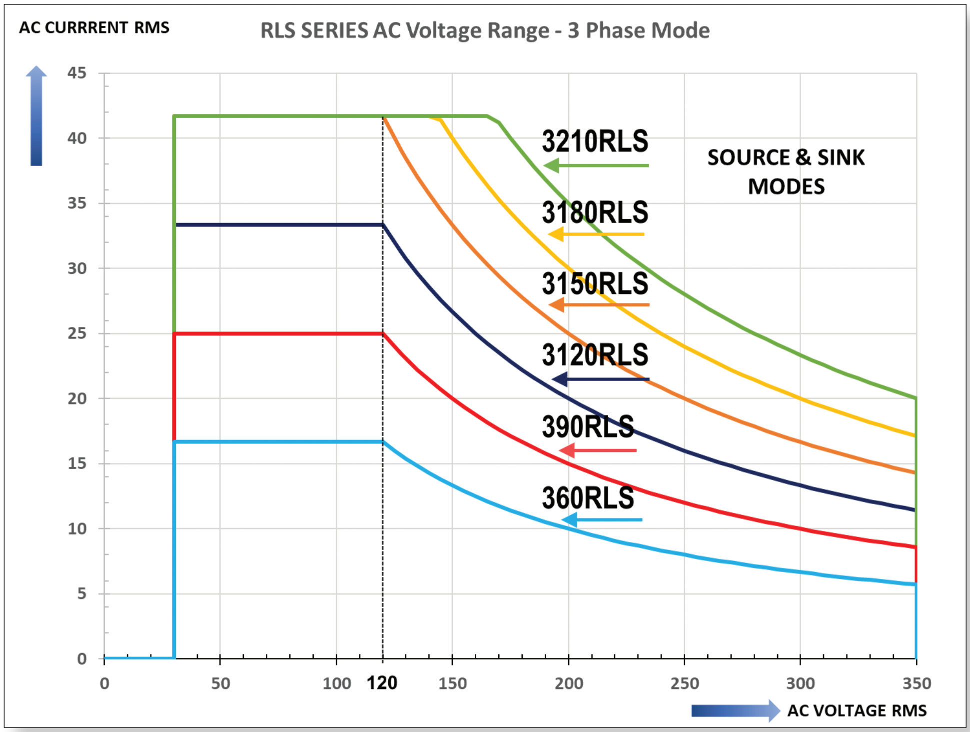

Figure 15: Voltage vs Current Charts for all RLS Models

The ELZ Series offers dual voltage ranges with maximum RMS voltage and current limits for each of four quadrants as shown in Figure 16. These limits apply to both AC mode.

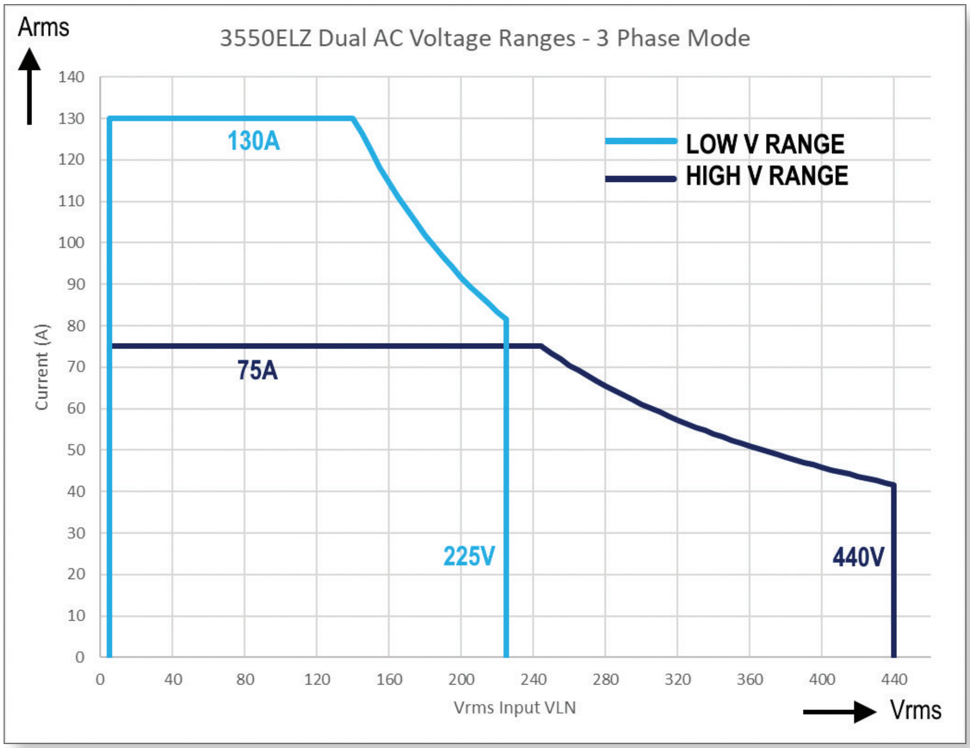

Figure 16: Model 3550ELZ High V range (black) and Low V range (blue)

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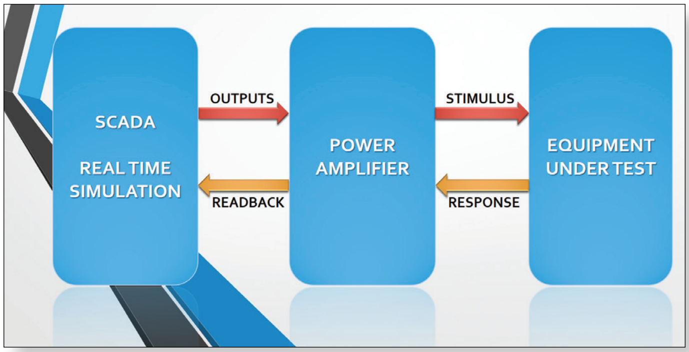
RLS & ELZ Series - AC & DC Load Modes

Applications

E-Mobility

Renewable Energy

Power Hardware in the Loop (PHIL) Test



Summary

Pacific Power Source Regenerative AC Loads are essential tools for testing energy producing, grid connected products like solar and wind inverters as well as bidirectional electric vehicle chargers.

To learn more about these RLS and ELZ Series, follow this link:

https://pacificpower.com/products/regenerative-grid-simulator-rgs-series/

https://pacificpower.com/products/regenerative-electronic-load-elz-series/

Customer Support

For application support, contact Pacific Power Source's Customers Service - Toll Free US: +1 (800) 854-2433 or your local authorized Pacific Power Source distributor or send an email to support@pacificpower.com.

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