



PLECS

*DEMO MODEL*

## Single-Phase Active Filter

### Shunt Active Filter with Hysteresis Controller

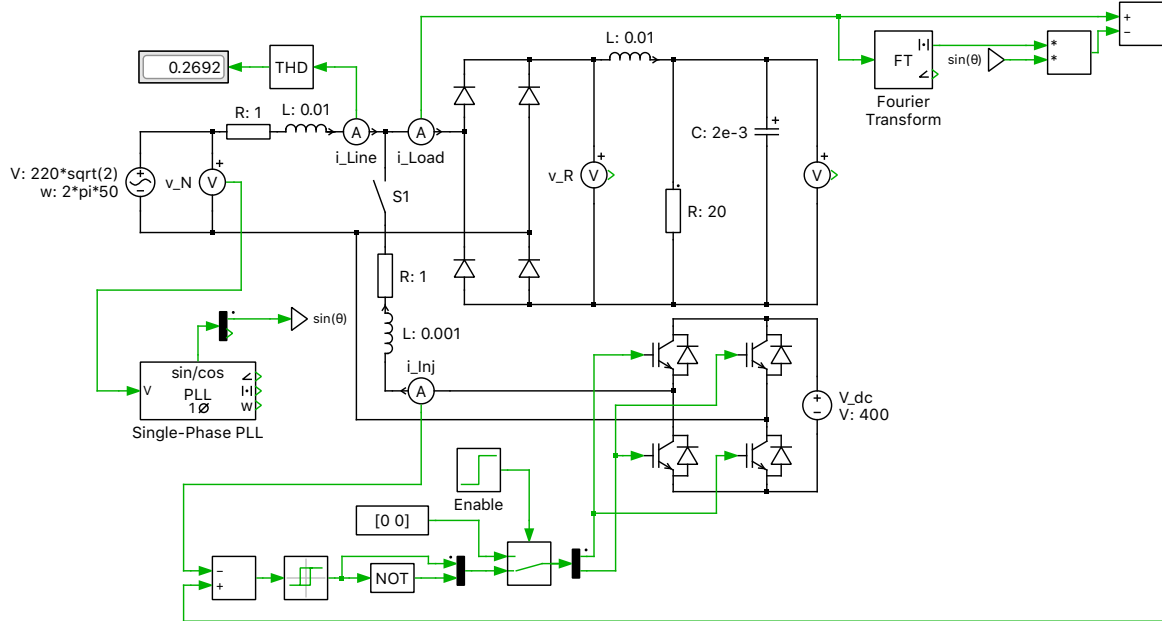
Last updated in PLECS 4.5.1

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# 1 Overview

This example demonstrates a single-phase diode rectifier with a shunt active filter circuit and hysteresis current controller. A 220 V, 50 Hz residential utility supplies a 20  $\Omega$  DC load via a full-wave diode rectifier resulting in source current rich in harmonic content. The active filter circuit can inject reactive and harmonic currents so the harmonic content of the rectifier circuit does not propagate to the utility supply.



**Fig. 1: Single-phase diode rectifier and active filter**

## 2 Electrical Model

A DC load and diode rectifier are connected to a 220 V<sub>rms</sub> mains, representing a common household load. Due to the highly non-linear nature of the passive rectification of the diodes, which draw chopped half-wave currents from the source with double line frequency, the power quality associated with the load will be poor. These distorted currents drawn from the local distribution network are typically unwelcome and may not meet certain standards, such as IEEE-519.

Several strategies exist to reduce the harmonics created by this rectifier topology, including passive filter networks. A shunt active filter has the additional advantage of dynamic compensation due to its controllability. The circuit adds a two-level voltage source inverter (VSI) in parallel to the load that can inject a controlled current into the network. The load current is sensed, and the equal and opposite harmonic content of that current is then added back to the load via the shunt branch.

Sufficient DC voltage is required for the VSI to produce the required currents. In this case, a stiff DC voltage of 400 V is used, although in practice a capacitor would be suitable since the VSI output is purely reactive. For an ideal converter operating in steady-state, zero net-power is exchanged with the network over a line-cycle.

### 2.1 Control

### 2.2 Reference Current Calculation

In order to generate a reference current for the VSI, a feedback current signal must be calculated. This is done by subtracting the fundamental load current from the total load current, which then provides the unwanted harmonic content that we want to reject. The fundamental load current must be synthesized since we want it to be in phase with the utility.

A Fourier Transform can be applied to the load current to measure the magnitude of the fundamental component,  $|i_{\text{load,fundamental}}|$ . A Phase-Locked Loop (PLL) from the PLECS component library in SOGI configuration (Second Order Generalized Integrator) is attached to the source and generates the desired angle of the load current,  $\theta$ , which is in phase with the voltage source. With these two quantities, the VSI's current injection reference signal is:

$$i_{\text{inj-ref}} = i_{\text{load}} - |i_{\text{load,fundamental}}| \cdot \sin(\theta)$$

This reference current is then fed to the controller for the VSI. Once the VSI produces the desired injection current, the mains effectively supplies only the fundamental component of the load current and the active filter circuit supplies the required harmonic and reactive components.

## 2.3 VSI Controller

A simple hysteresis control scheme is employed using a Relay block that has an error band of  $\pm 0.1$  A. The injection reference current is subtracted from the actual current injected into the system by the VSI. The generated modulation signals control the four MOSFETs in the VSI.

An enable circuit is included to delay the filter switching and avoid switching during the initial startup transient.

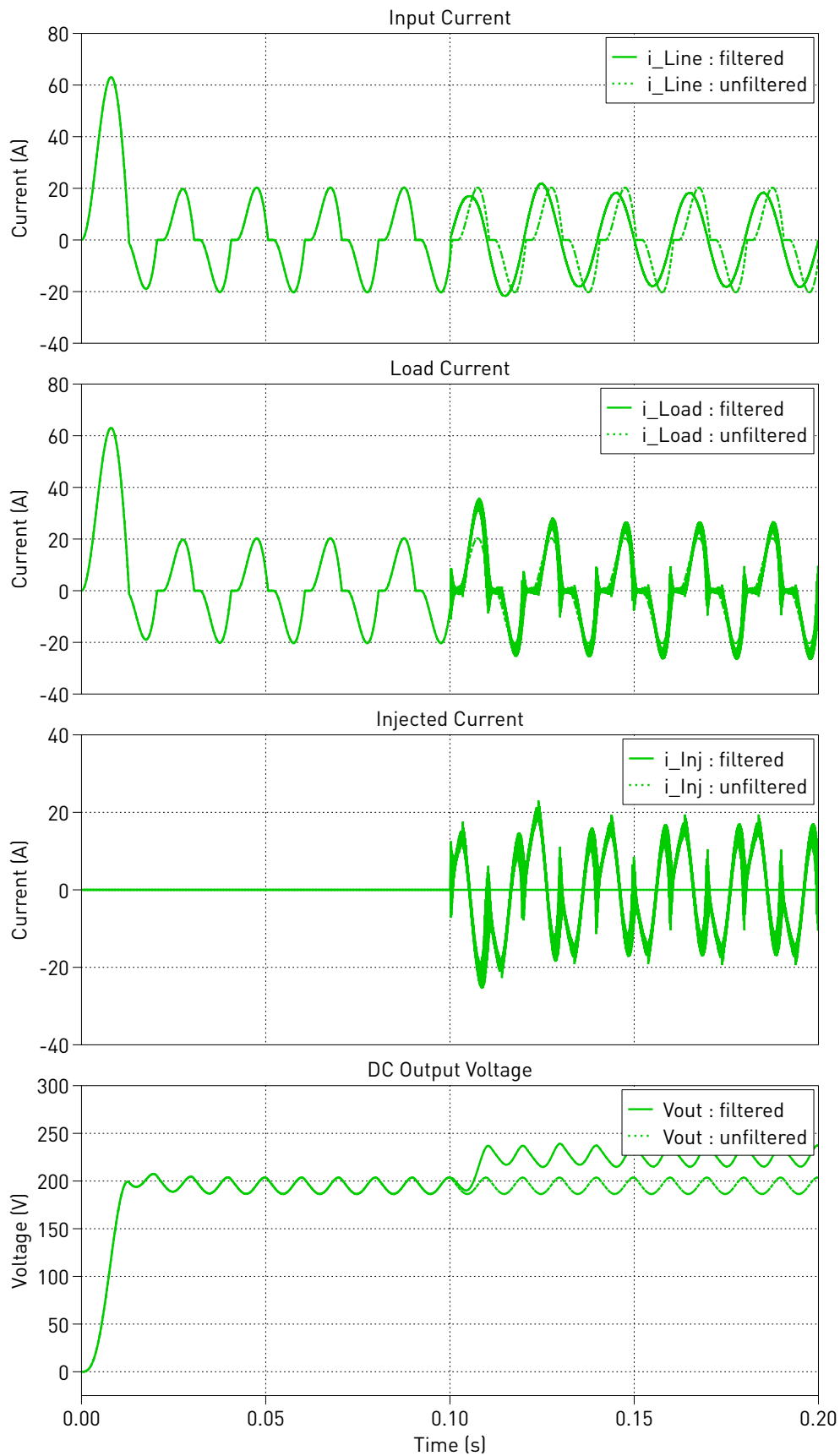
## 3 Simulation

Run the simulation with the model as provided. A Manual Switch (S1) is open by default and the active filter circuit is disconnected from the system. You will notice the highly non-linear, harmonic-rich input current waveform. Its total harmonic distortion (THD) is  $\sim 27\%$ . Next, close switch S1 by double-clicking on it and re-run the simulation. After an initial period, the controller is enabled and the input current becomes much more sinusoidal and has a THD of  $\sim 1\%$ , as shown in Fig. 2. Note that due to the additional harmonic current injected by the active filter, the load voltage increases. This can be reduced if necessary by additional voltage step down circuitry or more complex control schemes.

Opening the Power Scope, the average current injected by the VSI over a line cycle is near zero validating the assumption that a simple capacitor could be used as the DC voltage source for the VSI with appropriate controls to regulate the DC voltage.

## 4 Conclusion

This model implements a single-phase active filter to reduce the harmonic current distortion associated with a diode rectifier circuit. With a model consisting largely of basic PLECS library components with a very simple control structure, this demo highlights how a proof-of-concept model for the single-phase active filter can be quickly developed and evaluated.



**Fig. 2: Simulation results of system waveforms with and without active filter**

## Revision History:

PLECS 4.4.1	First release
PLECS 4.5.1	Updating PLL component with new library block

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