

PLECS

*DEMO MODEL*

## Swiss Rectifier with Digital Controller

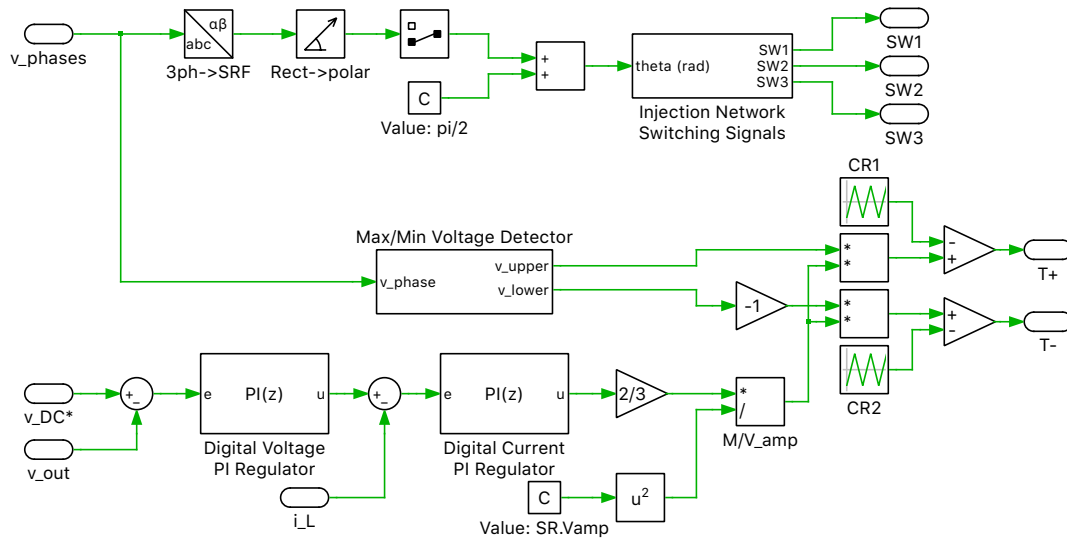
Last updated in PLECS 4.4.2

[www.plexim.com](http://www.plexim.com)

- ▶ Request a PLECS and PLECS Coder trial license
- ▶ Get the latest RT Box Target Support Package
- ▶ Check the PLECS and RT Box documentation



## 2.1 Control



**Fig. 2: Controller subsystem**

The controls of the SR are divided into two main parts: injection-network control and fast-switching controls.

The grid-side three-phase voltages are measured and the instantaneous phase angle is determined. The phase angle information is fed into a look-up table, which is used to generate the switching signal for the injection network switches.

The fast switches of the SR are controlled using a cascaded digital controller with an inner current loop and an outer voltage loop. The output voltage of the SR is measured and compared with a reference. The voltage error is fed into a digital voltage PI regulator and generates a current setpoint. The inductor current is measured and compared with the current setpoint. The error is fed into a digital current PI regulator, which generates a voltage setpoint. This voltage setpoint is translated into a modulation index ( $M$ ) given by:

$$M = \frac{2 \cdot V_{\text{set}}}{3 \cdot V_{\text{amp}}}$$

where  $V_{\text{set}}$  is the voltage setpoint generated by the current regulator and  $V_{\text{amp}}$  is the peak value of the three-phase grid voltage.

The three-phase voltage measurements are also used to determine the instantaneous maximum and minimum phase voltages ( $V_{\text{upper}}$  and  $V_{\text{lower}}$ , respectively). These are then used, along with the modulation index, to determine the duty cycle of the fast switches. The duty cycles,  $\alpha_+$  and  $\alpha_-$ , for  $T_+$  and  $T_-$ , respectively, are given by:

$$\alpha_+ = M \frac{V_{\text{upper}}}{V_{\text{amp}}}$$

$$\alpha_- = -M \frac{V_{\text{lower}}}{V_{\text{amp}}}$$

## 3 Simulation

Run the simulation with the model as provided to view the grid-side and load waveforms. The initial output voltage reference is set to 350 VDC. The output and filter capacitors are charged during the first 10 ms after which the system reaches steady state. The inrush current at startup and that due to step

changes in the output voltage and load, excite the resonant frequency of the input filter. This results in the oscillations seen in the current waveforms.

At  $t = 0.1$  s, the output reference voltage is stepped to 450 VDC. The output capacitor is charged up over the next 4 ms after which the system reaches its new steady state.

At  $t = 0.25$  s, the output reference voltage is maintained at 450 VDC and the load is halved. The output capacitor is discharged over the next 2 ms and the system again reaches steady state. In the “Load” and “Grid Side” scopes, save the trace and label them “phase-shifted carriers”.

Next, change the phase delay of the carrier signal in the controller labeled “CR2” to 0 s. Rerun the simulation and observe the effect of this switching strategy on the output current ripple. This represents the “minimal injection current ripple” switching strategy, while the phase-shifted carriers represent the “minimized dc inductor current ripple” switching strategy proposed by Soeiro. The interval specified in the preconfigured **Saved View** labeled “InjectionCurrent”, shows the grid-side currents for the three phases when the injection network switch (SW2) is kept on to inject current into the b-phase (red trace). The effect of the “minimal injection current ripple” switching strategy can be observed when comparing the b-phase grid current for the two proposed switching strategies over the interval specified in the preconfigured **Saved View** labeled “InjectionCurrent\_zoomed”.

## 4 Bibliography

- [1] Soeiro, T.B.; Friedli, T.; Kolar, J.W., “Swiss rectifier - A novel three-phase buck-type PFC topology for Electric Vehicle battery charging,” Applied Power Electronics Conference and Exposition (APEC), 2012 Twenty-Seventh Annual IEEE, pp. 2617-2624, 5-9 Feb. 2012.
- [2] Nussbaumer, T.; Heldwein, M.L.; Kolar, J.W., “Differential Mode Input Filter Design for a Three-Phase Buck-Type PWM Rectifier Based on Modeling of the EMC Test Receiver,” Industrial Electronics, IEEE Transactions, vol. 53, no. 5, pp. 1649-1661, Oct. 2006.

## Revision History:

PLECS 4.3.1	First release
PLECS 4.4.2	Update PI controller component

## How to Contact Plexim:

☎	+41 44 533 51 00	Phone
	+41 44 533 51 01	Fax
✉	Plexim GmbH Technoparkstrasse 1 8005 Zurich Switzerland	Mail
@	info@plexim.com	Email
	<a href="https://www.plexim.com">https://www.plexim.com</a>	Web

## *PLECS Demo Model*

© 2002–2026 by Plexim GmbH

The software PLECS described in this document is furnished under a license agreement. The software may be used or copied only under the terms of the license agreement. No part of this manual may be photocopied or reproduced in any form without prior written consent from Plexim GmbH.

PLECS is a registered trademark of Plexim GmbH. MATLAB, Simulink and Simulink Coder are registered trademarks of The MathWorks, Inc. Other product or brand names are trademarks or registered trademarks of their respective holders.