Power Factor Correction (PFC)

Exercise A: Simple Diode Rectifier

Figure 1 shows a simple diode rectifier, the output load is an ideal voltage source. In practice, at the DC side a huge capacitor is usually smoothing the output voltage, so that the constant output voltage in our model is a good approximation to reality.

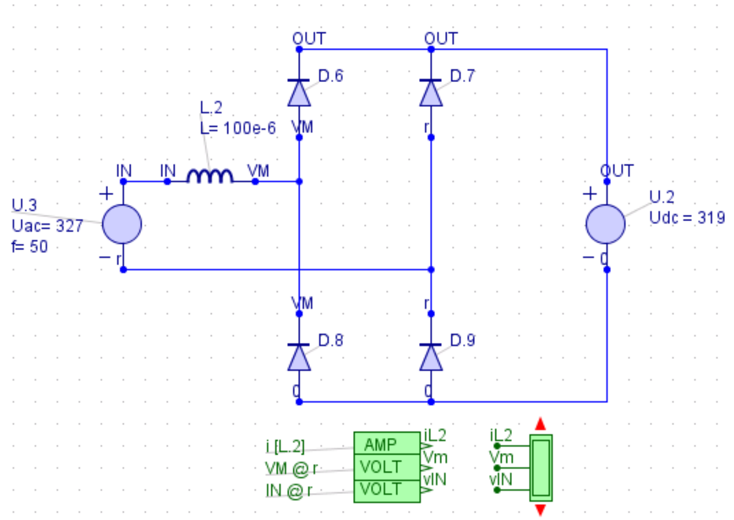

Fig.1

Implement the simulation model as shown in figure 1 in GeckoCIRCUITS, and use the component values as shown in the figure. Please consider that your simulation results will be dependent on the component values of the diodes. Use the standard diode settings in GeckoCIRCUITS, i.e. a forward voltage drop of 0.6V. Visualize the following simulation results within the GeckoCIRCUITS scope: input voltage u_{IN}, inductor current i_L and the diode bridge voltage u_m.

1. Set the simulation duration to 0.02 sec (a mains period) and select a reasonable value for the simulation step width dt. Use the built-in analysis tool of the GeckoCIRCUITS scope to calculate the mean value of the input active power. Which maximum input current i_L do you see at the inductor? Compare the simulation result with the theoretically calculated inductor maximum current, assuming a purely sinusoidal input current.
2. Which harmonics does the input current contain? You can use the Fourier analysis tool of GeckoCIRCUITS to visualize the input current harmonics. Visualize the current spectrum up to the 40th harmonic.
3. Calculate the THD value of the input current (herefore, again, you can use the built-in analysis tool of the GeckoCIRCUITS scope).

As you can see from your results, the simple diode rectifier feeds back harmonic distortions into the mains. In the following exercise part, we will discuss two simple topologies including a Power Factor Correction (PFC), which will significantly improve the THD.

Exercise B: PFC with a fixed tolerance bandwidth

Implement the simulation model of the rectifier according to figure 2, which includes a boost converter at its output. Please use the component values as given in the figure. Save the simulation model with a different name, e.g. *pfc_1.ipes*. Pay attention to the direction of the current flow within L_3, as the current measurement has to have the correct sign. You can enable the current direction visualization (pink arrows) in the menu “View->Flow-Direction”.

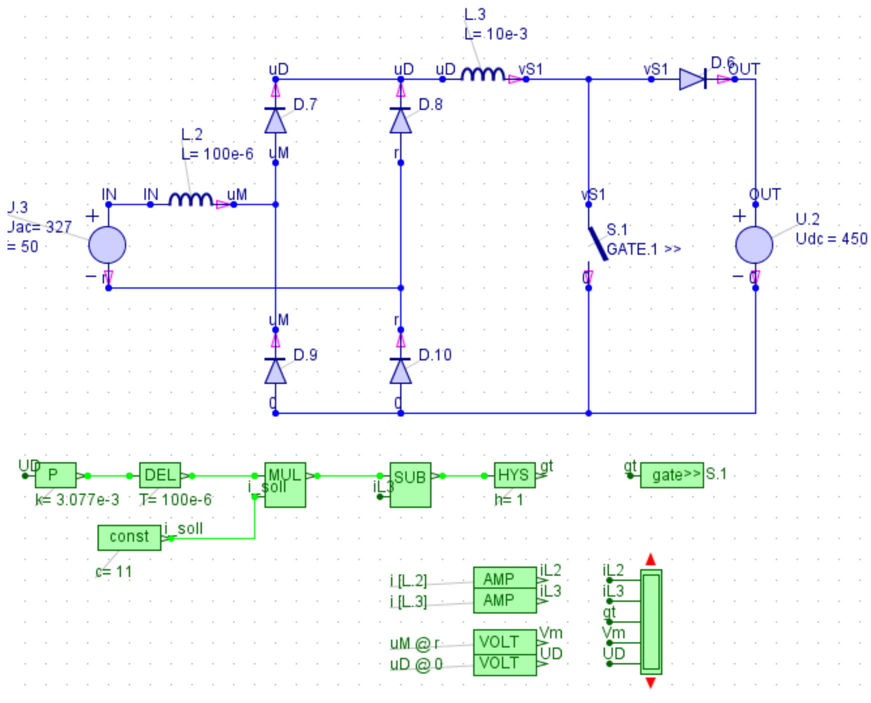

Fig. 2

Additionally to the values from exercise A, visualize the following circuit parameters: Voltage u_D and the inductor current i_{L3}. The boost converter that is used for the power factor correction is built by the inductor *L*, an ideal switch S_1 and the diode D_6. The switch is controlled by the gate signal *gt*. If the gate signal is zero, the switch is open, otherwise it is closed. Here, in contrast to the simple diode rectifier, the output voltage has to be above the amplitude of the input AC voltage. Otherwise, the boost converter cannot operate properly.

The model in figure 2 includes a simple control of the inductor current. The tolerance band control works in the following way: The inductor current i_{L3} is subtracted from its target value i_{soll} (SUB-Block in the control model) and the difference is then fed through to the input of a hysteresis block which controls the gate signal *gt*. The calculation of the reference value is done via multiplication of the normalized (and rectified) input voltage u_D with the desired input amplitude of the mains current.

4. Select the target value of the mains current to a value i_{soll} so that the mean active power of the rectifier corresponds to the value from exercise A.

5. Try to play with the component parameters. Can you find a correlation between the tolerance band width and the switching frequency of the control?

6. Have a look at the mains current close to its zero crossing. What do you observe?

7. Now, please re-set the output inductor value to 10 mH, and visualize the mains current spectrum up to 10 kHz via the Fourier analysis tool of the scope. Which harmonics do you observe? Calculate also the THD value and compare it to the THD value obtained for exercise A.

Exercise C: PFC with current proportional tolerance band

Another possibility for controlling the PFC is to vary the tolerance bandwidth proportional to the amplitude of the mains current. In this case, the current i_d should vary between $(1-k) \cdot i_{soll}$ and $(1+k) \cdot i_{soll}$, where i_{soll} is the current target value and k a constant in the interval $0 < k < 1$. You can find the corresponding simulation model in figure 3. Implement this simulation model in GeckoCIRCUITS, and use the given component values. Save your model with the file name *pfc_2.ipes*.

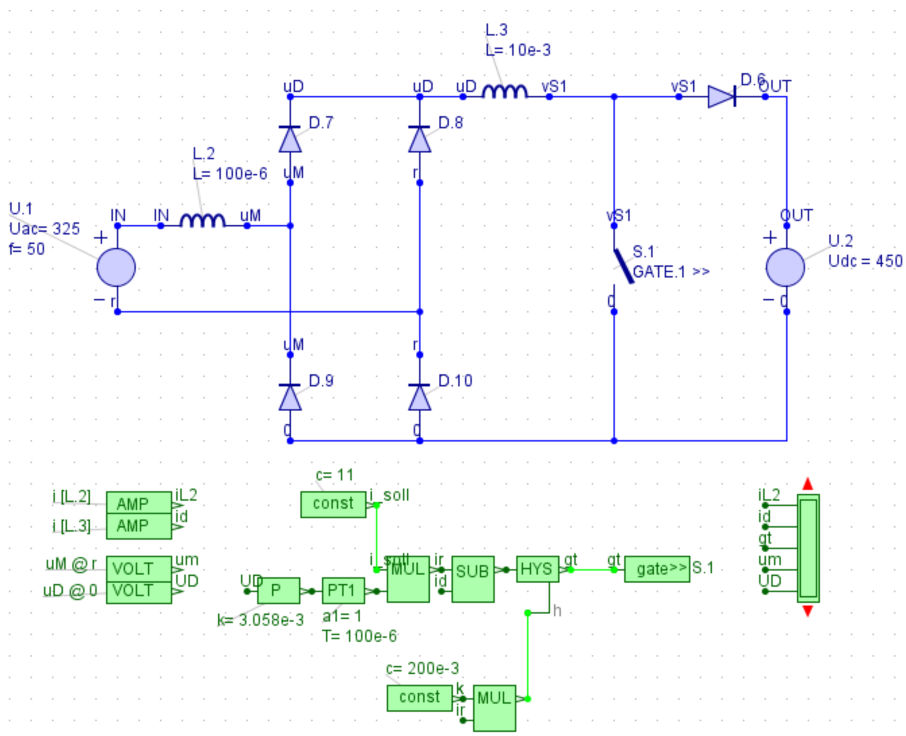

Abb.3

8. Set the target current value i_{soll} to the value from exercise part B. Please compare the current and voltage shapes as well as the mean switching frequency to the values from the previous exercise.

9. Visualize the mains current i_{L2} harmonics spectrum. How big is the THD?

10. Which influence does the tolerance bandwidth constant k have on the harmonics and the switching frequency?