1 Homework 3: Single-Phase Voltage-Source Inverter

Work with the pdf and the Moodle test at the same time!
A current control for the single-phase voltage-source inverter with an L-filter as given in Fig.1 will be investigated in this exercise (basic model is provided via Moodle). A P-controller will be implemented in Simulink. Use an inductance of L = 3 mH and a reference current of 20A·sin(ωt) with a fundamental frequency of 50 Hz which shall be in phase with the grid voltage. The system operates at a switching frequency of 10 kHz.
Hint: The low-pass filter in the model template serves only for visualization purposes. It is not necessary for the measurements performed in the following tasks. Use the Plecs scope for your measurements.

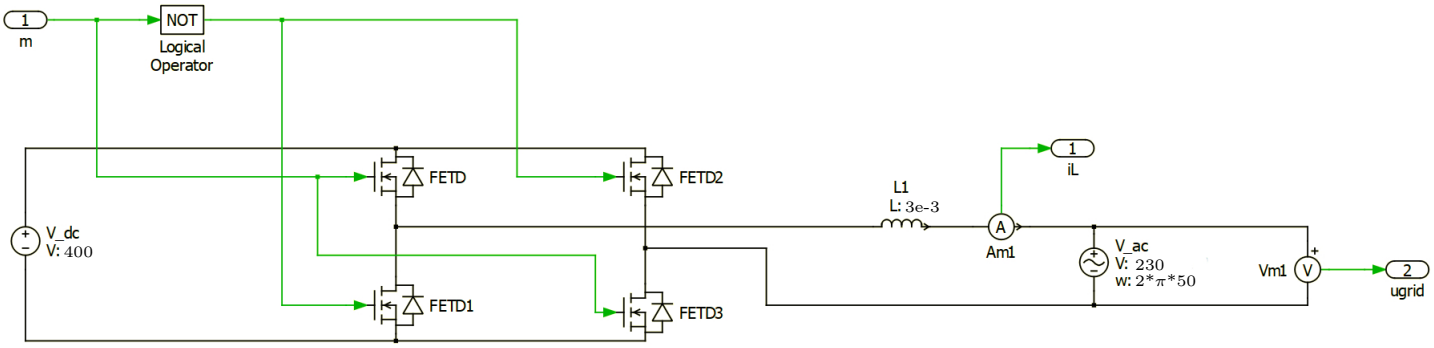

Figure 1: PLECS model of the single phase voltage-source inverter with an L-filter

1. Implement the current control with a proportional gain $K_P = 10\,\Omega$, in Simulink to regulate the grid current i_L. The modulator as well as the current sensor are assumed to be ideal. Use a simulation time of 100 ms and a maximum step size of 0.1 µs. Include your model to your ZIP file.
   - Simulate the maximum value of the grid current.
2. The dynamic stiffness shall be 20 Ω at a frequency of 1 kHz.
   - Calculate the proportional gain K_P to ensure the given dynamic stiffness.

From now on, use a controller gain $K_P = 10\,\Omega$.

3. The grid voltage can be seen as a disturbance for the applied voltage across the grid inductance. Add a compensator to the control model to eliminate the influence of the grid voltage. Include your model to your ZIP file.
   - Simulate the maximum value and the THD value of the grid current.
4. Add a disturbance grid voltage of $10\text{V} \cdot \sin(2\pi \cdot 1\text{kHz} \cdot \text{t})$ to the PLECS model that is superimposed to the grid voltage **(only for this task!).** Include your model to your ZIP file.
   Hint: The disturbance grid voltage doesn't influence the reference current.
   - Simulate the maximum value and the THD value of the grid current.
   - Which current flows at the given frequency of 1 kHz? Use the Fourier option in the PLECS scope.
5. Now, the current sensor introduces a delay of one switching cycle in the feedback path. Model the delay as a PT_1 element (first-order lowpass filter). Include your model to your ZIP file.
   - Measure the phase between the maximum of the grid current and the maximum of the reference current.
   - Calculate the poles for the closed-loop system.
     Hint: Use the function minreal() for the minimal realization of the transfer function.
6. Now, the PWM modulator also introduces a delay since the new duty cycle can be updated only once a switching period. Model the delay as a PT_1 element (first-order lowpass filter). Include your model to your ZIP file.
   - Calculate the poles of the close-loop system with the parameters calculated in the tasks before.
   - Simulate the peak current.
   - Measure the phase between the maximum of the grid current and the maximum of the reference current.
   - Calculate the poles of the closed-loop system for $K_P = 0.7\ \Omega$.

7. Questions
   - How can a system be stabilized without changing the proportional gain K_P ?
     - Increase of grid inductance L
     - Decrease of grid inductance L
     - Increase of the switching frequency
     - Decrease of the switching frequency
   - With the design method of the root locus the following parameter cannot be investigated.
     - poles of the open-loop system
     - damping of the closed loop system
     - poles of the closed-loop system
     - overshoot of a step response of the closed-loop system
   - A PI controller...
     - ... has no steady-state error in amplitude and phase for sinusoidal values.
     - ... has no steady-state error in amplitude and phase for dc quantities.
     - ... has high dynamic due to the integral gain.

Submission Information All numerical values should be submitted in RWTHmoodle. As RWTHmoodle does not support the English decimal separator, you have to enter the German decimal separator (,) instead. Please only enter values with three significant digits. You will find the submission mask under sections → Homework.
You have to create a ZIP file including the following objects:

- Task_1.slx
- Task_3.slx
- Task_4.slx
- Task_5.slx
- Task_6.slx

Please use the following convention for naming your zip file:

- Excercise{No}_Solution_{MatrNo}_{LastName}_{Firstname}.zip
- For Example: Excercise1_Solution_007007_Mustermann_Max.zip

The ZIP file should be uploaded into RWTHmoodle.

Simulation Settings The following settings should be set when you simulate (stock settings):

Parameter/Setting	Value/Setting
Diode turn-on threshold	1e-3
Type	Continuous state-space
Number of consecutive gate signal changes	100
Advanced->Tolerance	1e-6

Table 1.1: PLECS Settings

Parameter/Setting	Value/Setting
Solver Type	Variable-step
Solver selected	ode23s (stiff/Mod. Rosenbrock)
Relative tolerance	10e-6
Absolute tolerance	auto
Min step size	auto
Max step size	100e-9
Initial step size	auto
Shape preservation	Disable All
Number of consecutive min step	1
Zero-crossing control	Use local settings
Algorithm	Non adaptive
Time tolerance	10*128*eps
Number of consecutive zero crossing	1000
boxes	unchecked

Table 1.2: Simulink Settings