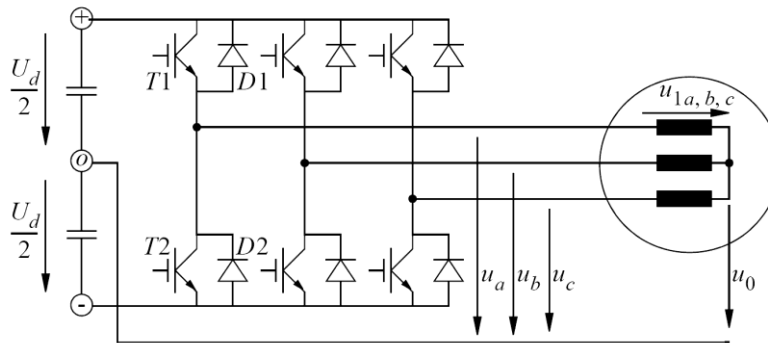


A Simple Three-Phase Inverter Model

Introduction

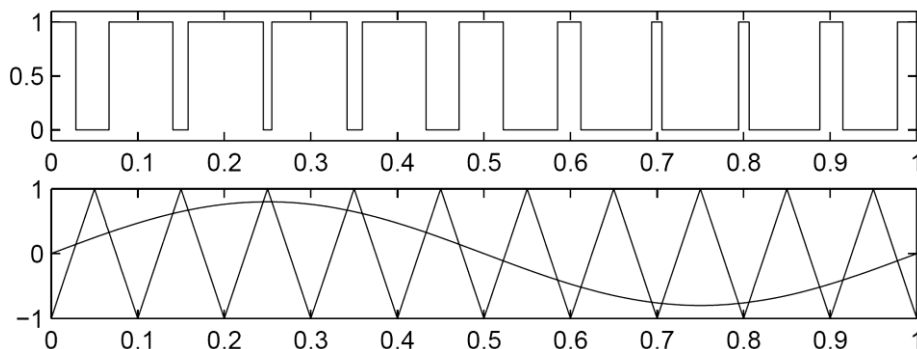
We will build a simple model of the three-phase inverter, as given in the figure below. Such a converter is in practice only a part of a complex power electronic system. For instance, in traction applications, the DC side is usually connected via a rectifier to the mains. Additionally, the control of the switches will be modeled in this exercise. The exercise is focusing on the modulator which controls the bridge legs via the “undershoot operation”. You will first build and test the modulator within GeckoCIRCUITS. Then, you connect the modulator with the power circuit, with the aim to analyze the behavior of the converter at different operating points.



The Modulator

Each of the converter bridge legs switches a phase of the AC output side either onto the positive or negative DC input terminal. Hence, every bridge leg is a switch between two different circuit states. Mathematically, we can express this into a switching function S for each bridge leg phase a , b and c , which can have the two values 0 and 1: $S_a = \{0, 1\}$ $S_b = \{0, 1\}$ $S_c = \{0, 1\}$.

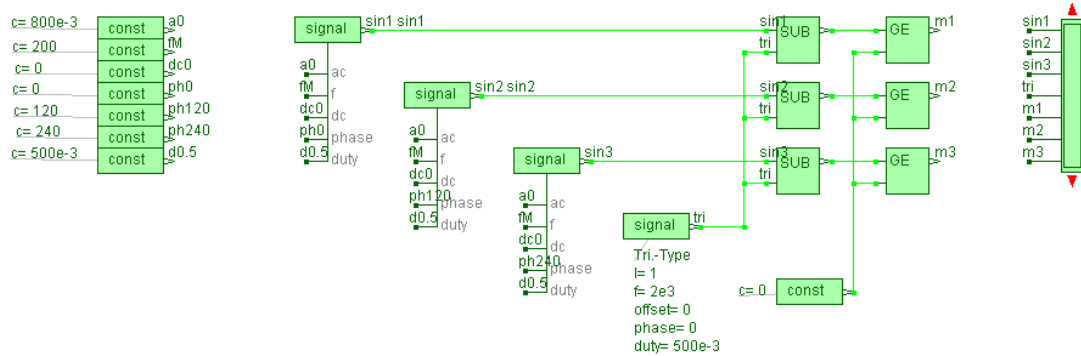
For the modeling of the switching function, we use the so called „undershoot operation“. The modulator is using a voltage value to calculate a corresponding pulse width signal (PWM). We shortly discuss the principle of the undershoot operation:



As you can see in the figure above, the switching state is $S = 1$, when the sinusoidal control signal u_{st} is bigger than the triangular signal u_{tr} , otherwise, $S = 0$.

Now, build the modulator with undershoot operation in GeckoCIRCUITS. The modulator should generate the three-phase switching pattern for the power switches, using phase-shifted sinusoidal input signals. You will need the following control blocks for building the modulator: “Signal Source”, “SUB” and “Greater Equal (GE)”.

To generate a control schematic that is not too cluttered, you can use labels instead of the green control wires. When to labels have the same name, they will behave as connected.



Sinusoidal signal generator:

- Use three „signal sources“ to get the three-phase sinusoidal control signals. The signal sources should be phase-shifted with 120 degree, respectively.
- Set the modulation ratio a_0 (amplitude of the sinusoidal control voltages) to $a_0 = 0.8$.
- The frequency should be set to f_{st} is 200 Hz.

Triangular signal:

- You will get a triangular comparator signal, when you set the type of an additional signal source to „triangular“.
- Set the switching frequency of the triangular signal to $f = 2000$ Hz.

Comparator

- Using a subtraction block (SUB) and a comparison block (Greater Equal, GE) to produce the three control signals for the power circuit.
- The greater-equal block should work the following way: For input values larger than 0, the output value should be 1, otherwise, 0.

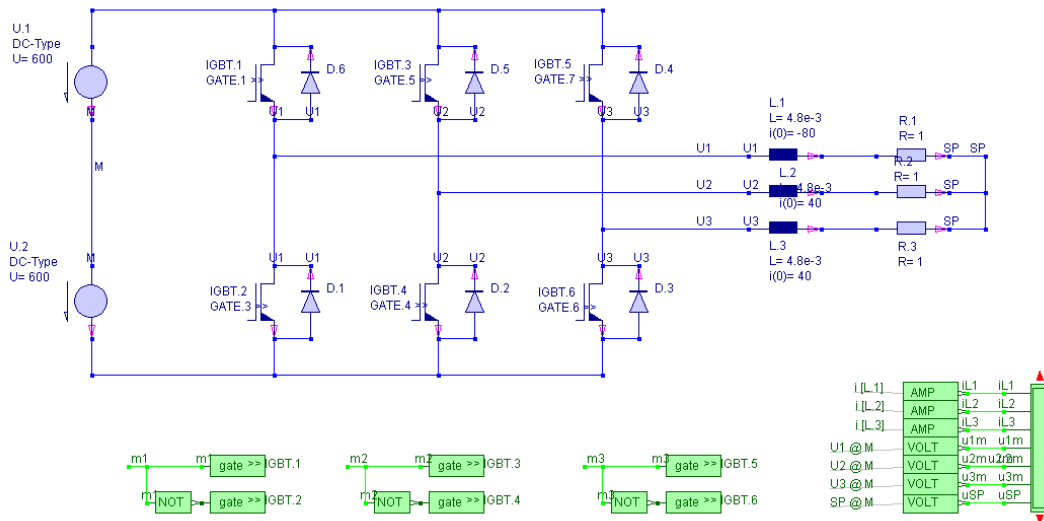
Now, please test your modulator by applying sinusoidal input values, and visualize the output signals together with the inputs in a GeckoCIRCUITS scope. Please also consider to change the simulator step-width dt to a smaller value, since the default value of $dt = 1 \mu\text{sec}$ is not small enough.

Modeling of the Power Circuit

After finishing and testing the modulator, we will build the power circuit in GeckoCIRCUITS (see the figure below). Therefore, you will use the circuit components “IGBT”, “Diode”, “Inductor”, “Resistor” and “Voltage Source”. The inverter is connected to a three-phase RL load ($R = 1 \Omega$, $L = 4.8 \text{ mH}$).

The two switches within a bridge leg will be switched synchronously. Therefore, you can produce an inverted control signal to $m1$, $m2$ and $m3$ using the “NOT” signal blocks.

In reality, you would have to ensure that the DC voltage is not short-circuited over a bridge leg by introducing a delay between the two switches. However, we don't include this into our model.



After finishing the power circuit model in GeckoCIRCUITS, please visualize the following circuit properties within the GeckoCIRCUITS scope: Phase currents, phase voltages, zero-voltage between the RL load star point and the midpoint of the DC input voltage.

As a reasonable simulation time, you could select for example $T = 20$ ms. Additionally, visualize the following space-vector properties using the space-vector plotter block from GeckoCIRCUITS: output voltage, mean-value of the output voltage (averaging time: one switching period) as well as the space vector of the load current.

To accelerate the time to reach steady-state, you can use reasonable initial values for the three inductor currents. Hereby, please consider that the three initial currents must add to zero – otherwise the solver might have a problem.

Simulation and Analysis

1. Start the simulation and look at the simulation results in the GeckoCIRCUITS scope. Which amplitude does the output voltage fundamental frequency have? You can use the Fourier analysis tool within the scope to calculate the fundamental amplitude.
2. Connect the midpoint of the input voltage and the star-point of the RL load. How do the converter output voltage and currents change, in comparison to the case without midpoint connection? How big is the current ripple in the inductors in both cases?
3. Use the Fourier analysis tool of the scope to visualize the spectrum of the output voltages and currents up to a frequency of 5000 Hz. Do this analysis for both cases: with and without midpoint connection.
4. Vary the values of the switching frequency, modulation ratio and inductance values. Which influence on the current harmonics do you observe?