Faculty of Technology
Department of Electrical Engineering
Academic Masters: CE+RE
Lab: Advanced power electronics

Lab: N° 01

Isolated Half-Bridge DC-DC Converter

Lab objectives

Isolated DC-DC converter has many advantages over the conventional regulated (linear) power supply, in particular its good efficiency and its small size. In this Lab, we propose to study the behavior of the symmetrical half-bridge power supply as one of well-known isolated topologies in switched-mode power supplies. It is a derivative of the buck converter that transfers directly the energy from the source to the load.

Converter circuit diagram

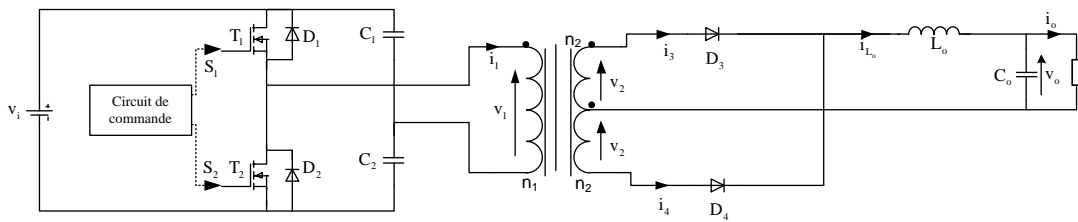The block diagram of the considered isolated DC-DC converter is illustrated in figure (1).

Figure (1): Half-bridge converter

The secondary voltage v_2 of the transformer is rectified, and then filtered by an LC filter. The role of the capacitor is to smooth the output voltage supplying a load resistor R.

Control strategy

The control signals of the two transistors are generated according to the timing diagram presented in Figure (2). Note that T_{sw} denotes the switching period and D the duty cycle of the isolated DC-DC converter.
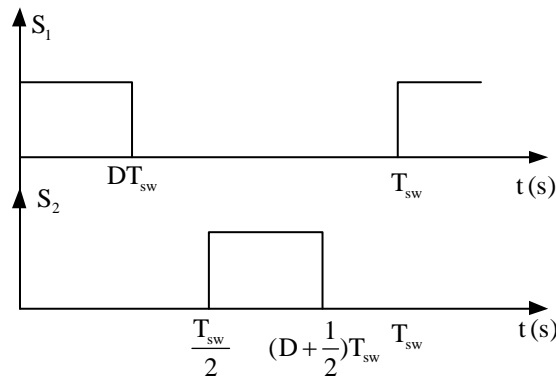
Figure (2): Switching signals

Theoretical study

In the following, we assume that the magnetic core of the transformer is linear and the switching elements are ideal switches. Also, the output voltage is assumed to be ripple free.

1°) Analyze the operation of the converter over a switching period T_{sw} by indicating the four possible modes.

2°) Calculate the value of the output voltage v_o in terms of v_i, D, and m with $m = n_2/n_1$.

3°) Establish the differential equations governing the operation of the converter and deduce the linearized model around its nominal operating point.

4°) Show that the linearized model of the converter can be represented by the circuit of figure (3). Give the values of the independent and dependent sources shown in this figure.
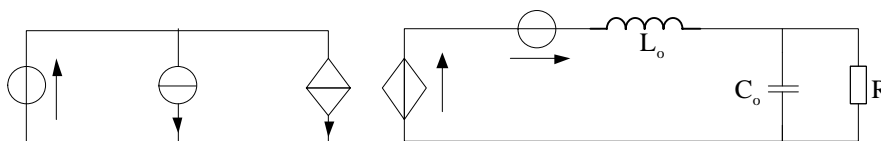

Figure (3 : Equivalent electric circuit of the linearized model

Simulation study

- Open loop operation

The converter simulation circuit in the SimPowerSystems environment of Simulink is given in figure (4). The converter has a power of 300W operating at a switching frequency $f_{sw} = 100\,kHz$. The HF transformer used is assumed to be linear with negligible resistance and leakage inductance. Its magnetization resistance and inductance are 500pu each.

The numbers of primary and secondary turns are $n_1 = 3, n_2 = n_3 = 1$. The other values of different components are mentioned in the same figure and the values of which are as follows: $V_i = 425\,V$, $r = 10\,m\Omega$, $R_1 = R_2 = 100\,k\Omega$, $C_1 = C_2 = 100\,\mu F$, $C_b = 10\,\mu F$, $L_o = 100\,\mu H$, $C_o = 220\,\mu H$, $R = 2.61\,\Omega + 10.4566\,\Omega$. The internal parameters of each transistor are: $R_{on} = 1m\,\Omega$, $L_{on} = 0\,H$, $R_d = 1\,m\Omega$,, $V_f = 0\,V$ and $R_s = 10\,\Omega$.
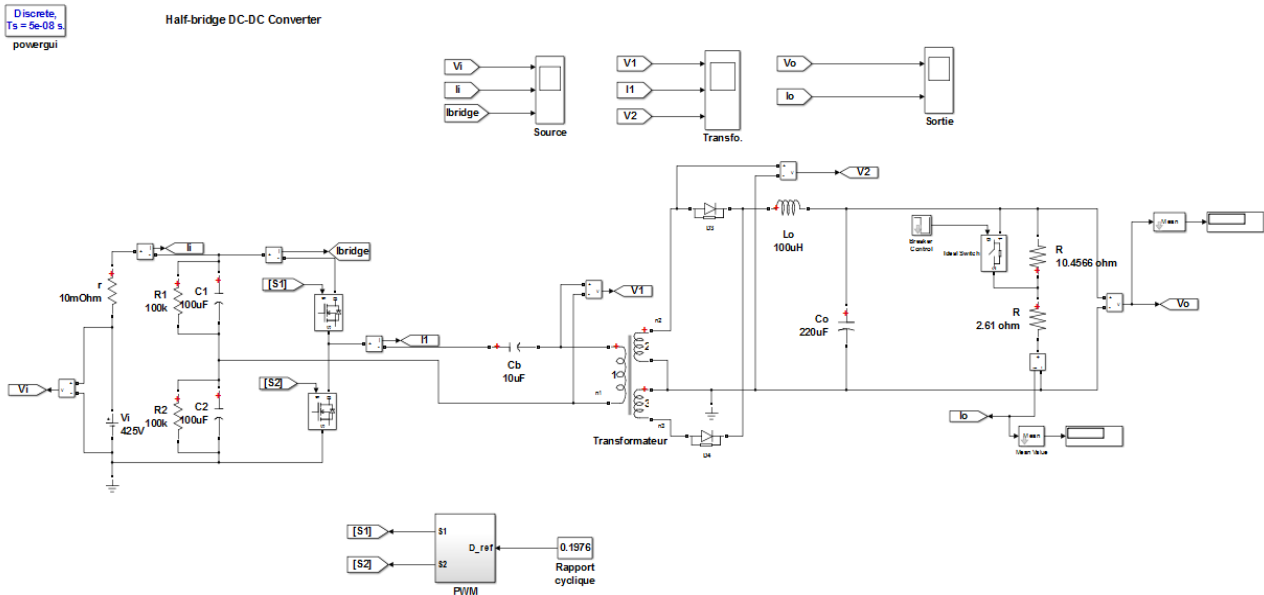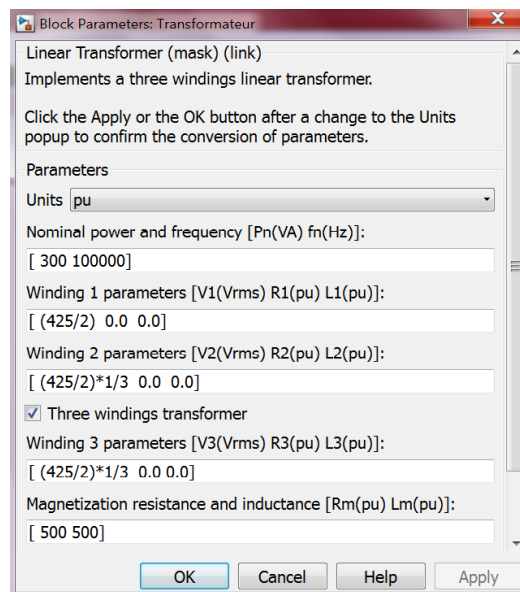

Figure (4): Simulation scheme of isolated DC-DC converter

The parameters of the transformer assumed to be perfect are given in the following dialog window:

The converter is controlled by a PWM technique, which consists of comparing the duty cycle to a sawtooth carrier of frequency $f_{sw} = 100\text{kHz}$ and unit amplitude using the 'Repeating Sequence' block. Note that the 'Clock' block has a frequency of $f_{sw}/2$, as shown in figure (4).
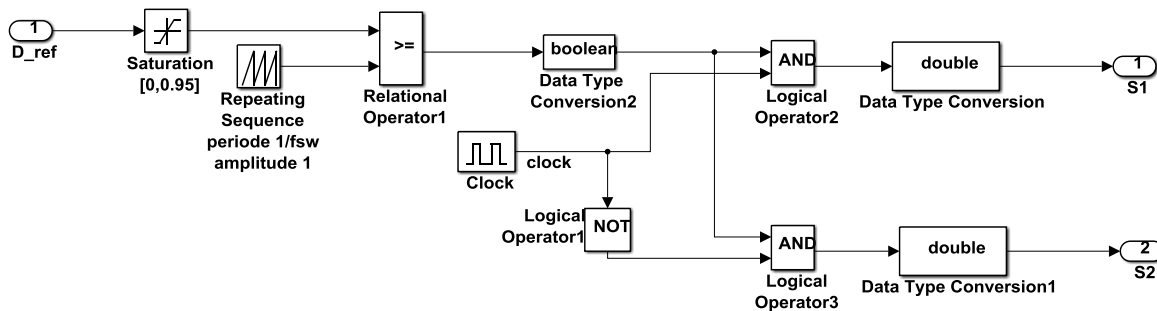

Figure (5): PWM control of the DC-DC converter

1°) Justify the role of the resistances R_1 and R_2 as well as that of the capacitance C_b.

2°) Explain the principle of switching pulses generation illustrated in figure (5).

3°) Calculate the duty cycle D_ref required to have a voltage of $V_o = 28\,\text{V}$.

4°) Simulate the converter over a horizon of 0.1s with a sampling period of 50ns. An increase in load resistance is introduced during the time interval $[0.03 \quad 0.07]\text{s}$ by controlling the ideal switch.

      a°) Record the curves of the quantities indicated on the three 'scopes' of figure (4) and interpret the results found.

      b°) Measure the output voltage for several values of the duty cycle and draw the curve $V_o = f(D)$. Comment on the curve found.

5°) Write a program in Matlab Function block allowing you to carry out the PWM control shown in Figure 5.

- Closed loop operation

The closed-loop control of the converter necessarily passes through the regulation of the output voltage to a given reference V_{o_ref}. The adopted control scheme is illustrated by figure (6). The regulator provides the duty cycle value essential to maintain the output voltage at its reference value $V_{o\_\text{ref}} = 28\,\text{V}$.
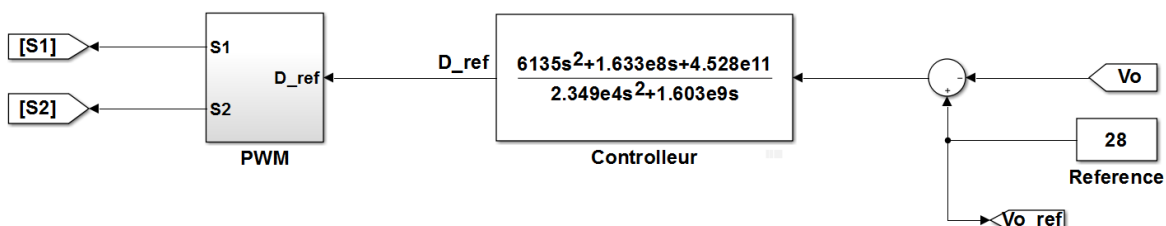

Figure (6): Output voltage control scheme

1°) List the methods commonly used to design a PID regulator.

2°) Show that the transfer function linking the duty cycle to the output voltage can be put in the following form:

$$G(s) = \frac{G_o}{\frac{1}{\omega_0^2}s^2 + \frac{Q}{\omega_0}s + 1}$$, where G_o, ω_0 and Q are to be calculated. Draw its corresponding Bode plot.

3°) Using the control diagram in figure (6), draw the same waveforms requested previously and comment on the results found.