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Title

EXERCISE 1: OPEN-LOOP BOOST CONVERTER

Course Name

EE-465 Industrial Electronics I

1 GUIDELINES

Reports on the topic of exercise sessions add to 40% of the course grade. Your report must not exceed 10 pages and must be based on the provided *Latex* template. Under no circumstance will late submissions be accepted.

2 OBJECTIVES

This exercise session focuses on the open-loop behavior of the PV system input stage: the boost converter (cf. Fig. 1). You will properly initialise the constants in PLECS, configure the solver to give sound results and recall the boost basic principles (current modes, ripple calculation, PWM).

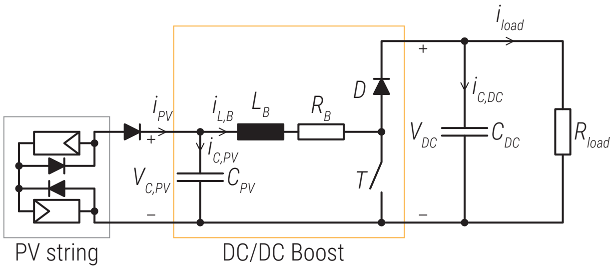

Fig. 1 PV system input stage. The inverter stage is replaced by an equivalent resistive load.

Table 1 Parameters set and design requirements for the boost converter.

$V_{C,PV}$	200-400 V	f_{sw}	10 kHz	$\Delta I_{L,B,pp}$	10 A	$\Delta V_{DC,pp}$	5 V
P_{nom}	20 kW	$V_{DC,nom}$	750 V	R_B	$2m\Omega$		

3 INTRODUCTION

A boost converter (cf. Fig. 2) is a one quadrant DC/DC converter ($I_{L,B}$, $I_{load} \geq 0$ and $V_{C,PV}$, $V_{DC} \geq 0$). The characteristic equation describing the function of the converter is:

$$1 - D = \frac{V_{C,PV}}{\langle V_{DC} \rangle} \tag{1}$$

where $\langle x \rangle$ is the periodic average of the variable x over a switching period and D is the duty cycle. We assume that the diode and the switch have ideal characteristics.

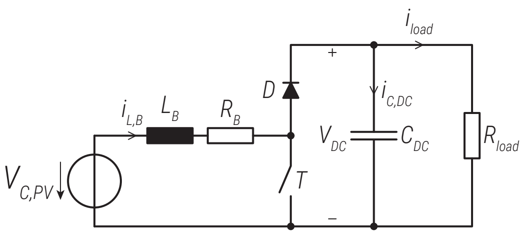

Fig. 2 Boost converter scheme used for simulations.

4 TASKS DESCRIPTION

1. Calculate R_{load} for a nominal power transfer (*write an equation and explain your reasoning*).
2. Size L_B and C_{DC} according to the requirements of Table 1. For this, the parasitic boost inductor resistance R_B is assumed to be 0. Moreover, the design should be robust and the requirements should be met in any possible working condition. This means that the input constraints such as nominal power (P_{nom}) and output voltage ($V_{DC,nom}$) as well as current and voltage ripple ($\Delta I_{L,B,pp}$ and $\Delta V_{DC,pp}$) need to be guaranteed for the voltage variations of $V_{C,PV}$ (200-400V). For this step, *write a set of equations to calculate L_B and C_{DC}, explain your reasoning for using these equations and how you determined the operating conditions to be considered*.
3. Explain what is the critical $\langle I_{load} \rangle$ value that guarantees continuous conduction mode, i.e. that $i_{L,B}$ never reaches 0 (*write an equation and explain your reasoning*). Calculate critical $\langle I_{load} \rangle$ in the worst possible operating condition (highest current ripple), assuming that the output voltage in fixed to its nominal value. What is the minimum power that the converter can process without entering in DCM? *Hint:* Also for this task you can assume to have a lossless operation ($R_B = 0$)
4. Verify and demonstrate with a switched model in PLECS that your boost converter design meets the requirements of Table 1.
   Hints:
   - You need to fill up the "IGBT Gate signal generation" subsystem to generate the desired 10 kHz pulse width modulated (PWM) signal.
   - Check that all the Simulation Parameters fit with your calculations or assumptions.
   - You will populate the "Averaged model" until task 5.
   - There are step functions prepared for the task 6, you should refer to steady state reached before the first step (zoom somewhere between t = 0.18 and t = 0.20 to get more stable results).
   - You can use cursor tools to perform the requested measurements.
5. Until this point you have worked with the switched model. Obtain and implement in "Average model" subsystem the average model of a boost converter. Present and explain the equations describing the system.
   Hint: You can partition the model of the converter in blocks.
6. Compare the state variables waveforms from the average model with the switched model for the following step changes:
   - A duty-cycle step change from 0.1 to the nominal duty-cycle (use $V_{C,PV} = 300\,V$)
   - A load step change from R_{load} to $R_{load}/2$
   - An input voltage step change from 300 V to 200 V

   Give a scope capture in PLECS and explain the effect.

5 REPORTING

Your results will be part of the first evaluated report.

- N.B: For each equation give your reasoning for using that equation and provide an explanation.
- For each scope capture use scope export: *File → Export → as PDF* using A4 paper size and Landscape orientation.
- Each scope plot needs to have a title and a legend in the title explaining which colour corresponds to which plot.
- Think about grouping plots of the same SI unit, i.e. voltages with voltages and currents with currents.
- Each figure of a scope capture (or any figure for that matter) needs to have a caption explaining (briefly) what is in the figure.