Maestría en Ingeniería en Automatización de Procesos Industriales

Design and implementation of Boost-type DC-DC converters with fractional order controllers from a CAD tool in SIMULINK / MATLAB

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IX Symposium de Posgrado

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1. Introduction

The supply of energy from a photovoltaic system to a load demands a large conversion efficiency provided by a DC/DC converter [1]. Several electrical parameters influence the behavior of this system. In consequence, the use of a controller is mandatory. We propose a method to design integer and fractional order lead-lag controllers [2], [3]. In contrast to other alternatives, like PID or sliding-mode controllers, this low-complexity, analytical method allows us to control until four parameters of the step response. These parameters are setting time, steady-state error, overshoot and the magnitude of the initial control signal, preventing saturation of actuators. The method resulted in a Computer-Aided Design tool which yields to a circuit level realization starting from the specifications. The application of CAD tools achieves the complete automation of industrial processes, from design to manufacturing, optimizing costs, quality, time and safety; as well as the technological integration of the areas [4].

2. Objectives

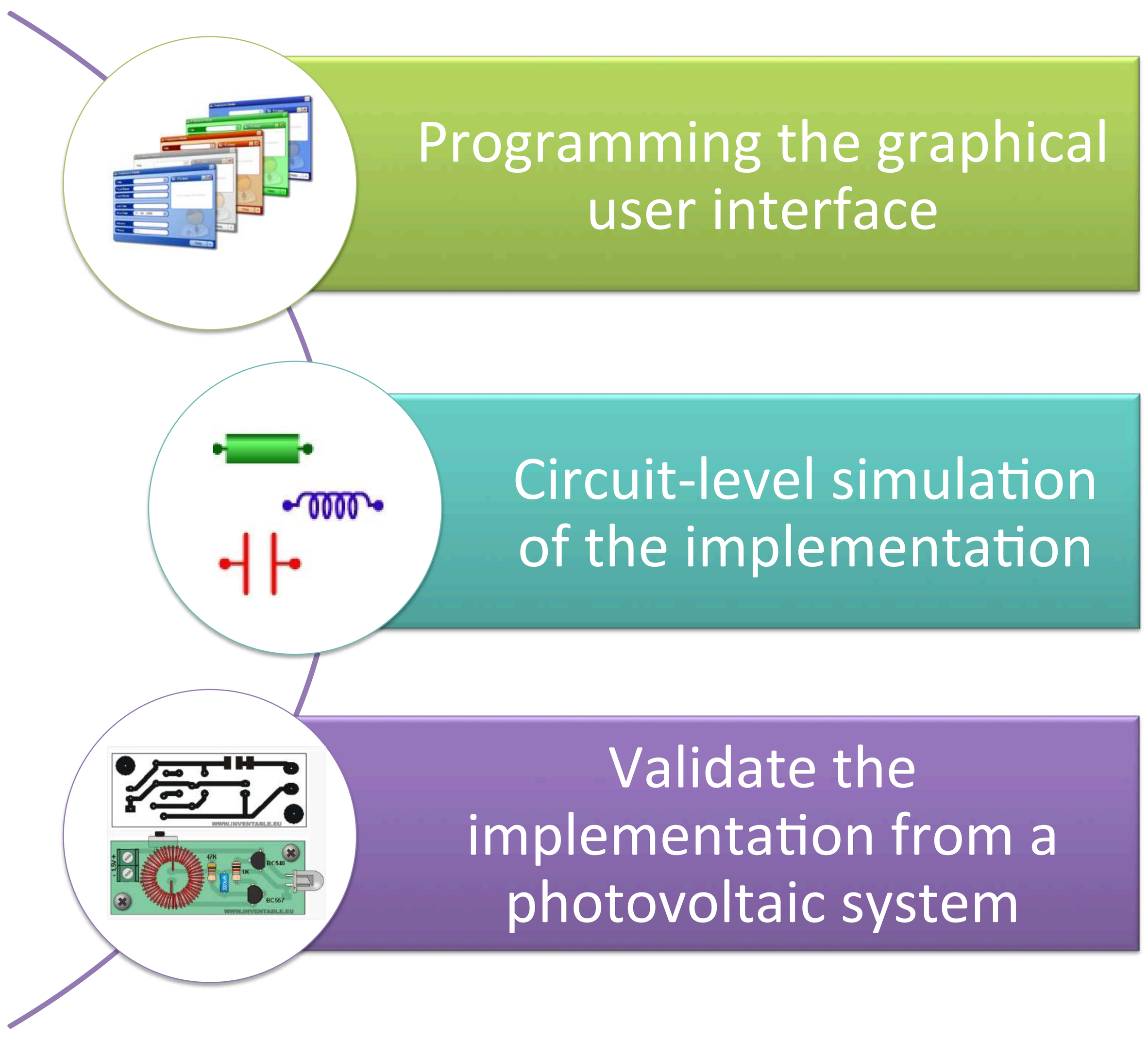
2.1. General objective

To develop a CAD tool in MATLAB / SIMULINK to design automation, circuit-level simulation and the implementation of Boost-type DC-DC converters.

2.2. Specific objectives

- To design a graphical user interface (GUI-MATLAB) that determines the parameters of the specified controls based on characteristics provided by the user.
- To incorporate into the GUI a simulation tool that provides the implementation at the circuit level of the controllers, efficiency and responses to the step and disturbances.
- To validate the CAD tool in a prototype photovoltaic system.

3. Methodology



Theorical Background

- Fractional derivative (Riemann-Lieuville).

$$D_t^{\alpha} f(t) = \frac{1}{\Gamma(m-\alpha)} \left(\frac{d}{dt}\right)^m \int_0^t \frac{f(\tau)}{(t-\tau)^{\alpha-m+1}} d\tau$$ (Ec.1)

- Lead-lag compensation of phase [3].

$$C(s) = K\left(\frac{1+\alpha\tau s}{1+\tau s}\right)$$ (Ec.3)

- Lead-lag compensation of phase of fractional order [4].

$$C(s) = K\left(\frac{1+\alpha\tau s^q}{1+\tau s^q}\right)$$ (Ec.4)

Figure 1. Methodology of the lead-lag compensation of integer and fractional order.

Programming methodology

Specifications by the user.

- Input voltage
- Switching frequency
- Load resistance
- Inductor
- Output voltage
- Duty cycle
- Voltage increase
- Capacitor

In order to operate the converter in continuous conduction mode, the inductance is calculated such that the inductor current I_L flows continuously and never falls to zero as

$$L_{min} = \frac{(1-d)^2 \cdot d \cdot R}{2 \cdot f}$$

Where L_{min} is the minimum inductance, d is duty cycle, R is output resistance, and f is the switching frequency of switch.

The output capacitance to give the desired output voltage ripple is given by:

$$C_{min} = \frac{d}{R \cdot f \cdot V_r}$$

Where C_{min} is the minimum capacitance, d is duty cycle, R is output resistance, f is the switching frequency of switch and V_r is output voltaje ripple factor. V_r can be expressed as:

$$V_r = \frac{\Delta V_{out}}{V_{out}}$$

Where the specifications of the control for DC / DC Converter type Boost.

- Percentage overshoot (M_p)
- Settling time (t_s)
- Steady state error (e_{ss})
- Order restriction (μ)

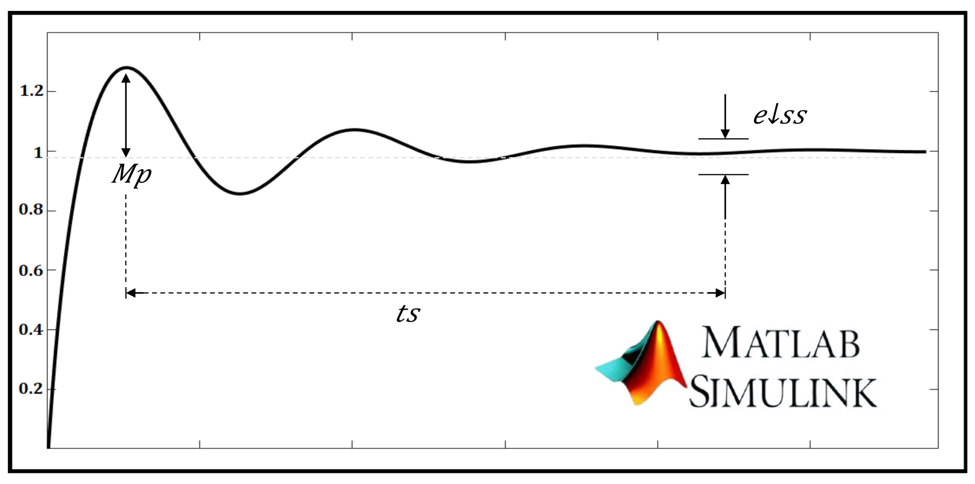
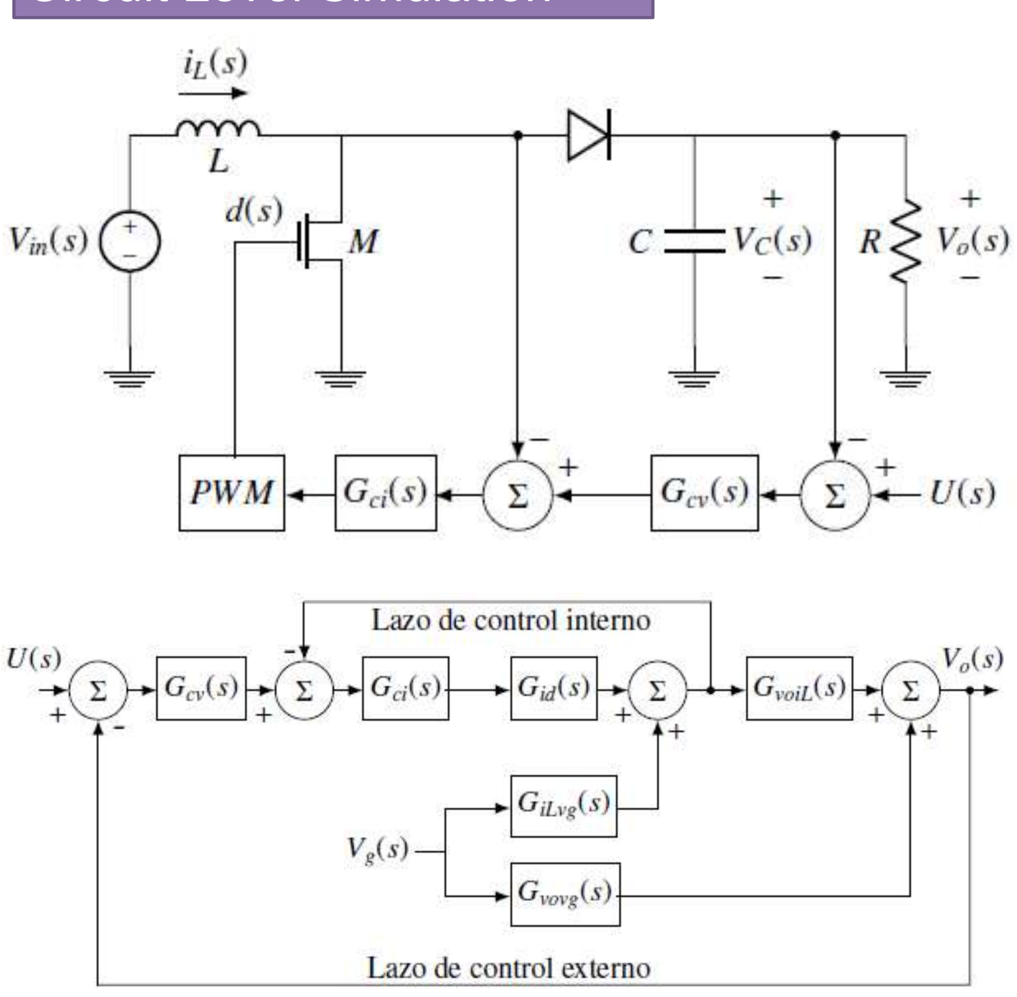


Figure 2. Methodology of the programming the graphical user interface.

Circuit Level Simulation



Circuit-level representation of the DC-DC converter and block-level representation of the control and transfer function of the converter.

Figure 3. Simulation tool at the circuit level of the implementation.

4. Results

GUI (MatLab Simulink)

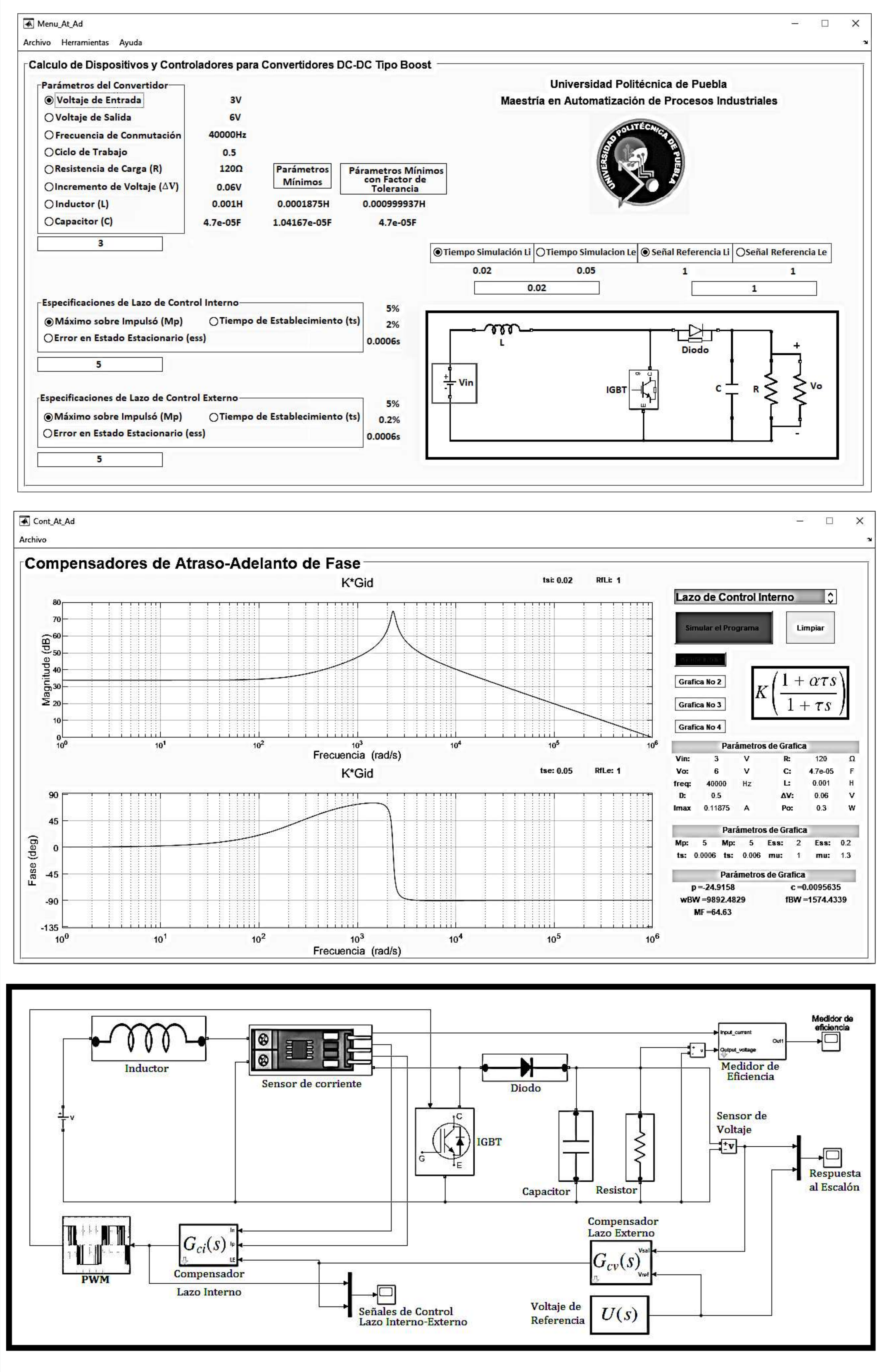


Figure 4. Graphical User Interface (MatLab Simulink).

Validate the implementation

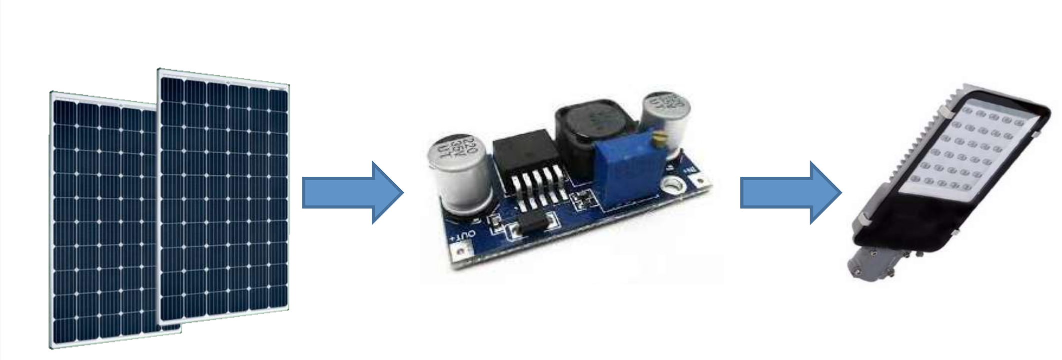


Figure 5. Photovoltaic System Prototype.

5. Conclusion

The Boost-type DC / DC converter raises the voltage and optimizes the energy efficiency of the solar panel; On the other hand, the fractional control has an additional degree of freedom to protect from overloads or saturation in the actuators and increases the speed of response in the converter. In addition, the CAD tool allows to reduce the control design time of the Boost-type converter.

Acknowledgements.

This research is supported by CONACYT. Gerardo Peña López master scholarship No. 864058 PNPC.

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