

Extract the transfer function of the Buck converter using PLECS software

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Abstract – Due to the importance of DC-DC converters in renewable energy systems, researchers face many challenges and difficulties in designing and analyzing models of DC-DC converters and extracting their dynamic equations that are used to design the systems control unit. In this paper, the Buck converter will be modeled using PLECS software. This software facilitates and speeds up the process of modeling, getting an accurate model, and extracting the transfer function. Without effort and calculation and in a very short time and without errors, unlike other methods, the bod diagram is also extracted using MATLAB software to extract the transfer function.

Keywords – PV Panel; DC-DC Buck Converter; Maximum Power Point Tracking MPPT; PLECS®; Transfer Function.

I. INTRODUCTION

Because of the significant decrease in the sources of non-renewable energies and the negative effects that result from them, and the increasing demand for them, the world is turning today to exploit renewable energies, including wind, solar and water energy,

Solar energy is one of the most important sources of renewable energy because of the advantages it provides in: large amounts of clean energy, low production costs, and a permanent source of energy. It is exploited using photovoltaic systems consisting

of a panel that feeds a load through a DC-DC converter,

It is an essential component in photovoltaic systems. It is used as the interface between the photovoltaic panel and the load for adaptation

The entire system is controlled by the duty cycle of the DC-DC converter, and the manufacture of a powerful controller requires designing an accurate linear module for the DC-DC converter and extracting the required transfer function. Linear modeling and the transfer function will be extracted

using a modern method, which is modeling using the PLECS software,

which can perform the modeling process for DC-DC converters, obtain accurate and correct.

linear models, and extract the required function quickly and accurately, without performing arithmetic operations and without any effort, unlike other traditional methods that require time and calculation with the possibility of making errors during the calculation and thus obtaining inaccurate models, many works has been done on modeling using PLECS, including:

Ciobotaru, M et al. (2006) simulated a PV system, using the PLECS toolbox, and tested and compared both simulation models [1]. Asadi, F.; (2018). Use PLECS® and MATLAB® software to model DC-DC converters and extract the dynamics of these converters. [2] Ahmed, O. A., & Bleijs, J. A. M. (2010) they analyzed a full-bridge DC-DC converter for fuel cell applications comparing simulation results with PSpice integrated with Simulink's PWM circuit via SLPS software and with converter simulation results using PLECS®, integrated with Simulink.[3]. Shao, S and others they describe and compare different modeling techniques and control methods for active dual-bridge (DAB) DC-DC converters, provide clear guidance on DAB controller design, and use PLECS® software to simulate the reviewed control methods.[4].

In this paper, first, the buck converter is modeled and then the Bode plot is extracted using PLECS® software, and finally, MATLAB® software is used to extract the required transfer function.

II. BUCK CONVERTER

It is a switching power source that converts a higher DC voltage at the input to another DC voltage of a lower value at the output. It provides the possibility of regulating the output voltage. It consists of the following elements: resistor $R = 5\Omega$, capacitor $C = 100\mu F$; Inductor $L = 100\mu H$, $V_s = 10$, $F_{switching} = 50$ khz.

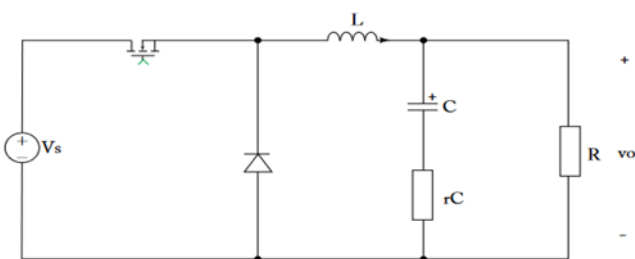


Fig.1. Schematic of a buck converter. MOSFET and diode are assumed to be ideal

III. PLECS® SOFTWARE

PLECS® is a software tool designed by [Allmeling and Hammer, 1999] used to simulate electrical circuits quickly and accurately. PLECS consists of two versions: The first version of Simulink, as its name suggests, runs in an L environment MATLAB® / Simulink means it is linked to MATLAB.

Version 2 works in conjunction with or separately from MATLAB, Version 2 tools can be used in the Simulink version, and Version 2 tools can't be used in Standalone Places.

In this work, the second standalone version is used. To plot a Buck converter circuit and extract the transfer function for the small signal, after adding "Small Signal Perturbation" and "Small Signal Response" blocks at the appropriate places in the circuit diagram.

IV. THE STAGES OF EXTRACTING THE SMALL-SIGNAL TRANSFER FUNCTIONS AND THE BOD DIAGRAM OF A PHOTOVOLTAIC SYSTEM USING PLECS®

First: To design the module petit signal for the Buck converter, we follow the following stages:

- Using the PLECS® Standalone graphical interface and toolkit, we draw the equivalent circuit of the Buck converter shown in the following figure 2 which is used to extract the v_o/d_s conversion function (ie the control and output transfer function).

The values of the previously mentioned components are entered into the obtained circuit.

- The "small signal disturbance" and "small signal response" blocks are added to extract the Bode Diagram, the latter being used in MATLAB software to extract.

Small signal transfer function that connects duty cycle and output voltage.

An equivalent circuit model of the Buck converter obtained using the graphical interface of PLECS software is shown in Figure 2:

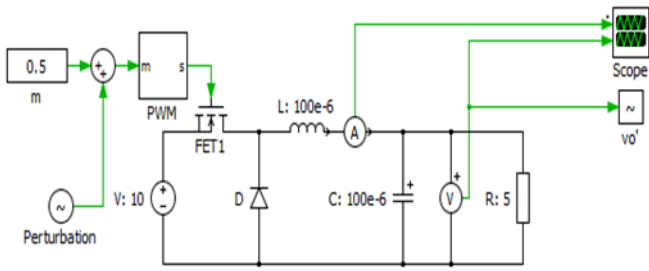


Fig.2. Buck converter equivalent circuit model using PLECS® software.

A. BODE DIAGRAM EXTRACTION

To extract the Bod diagram, the following steps are followed:

- Clicking on the “Simulation” button located at the top of the PLECS® widget bar.
- Clicking on the “Analysis Tools” button.
- Click on "control of output TF"(impulse response).
- Clicking on “start analysis”

We get the Bode diagram of the Buck converter

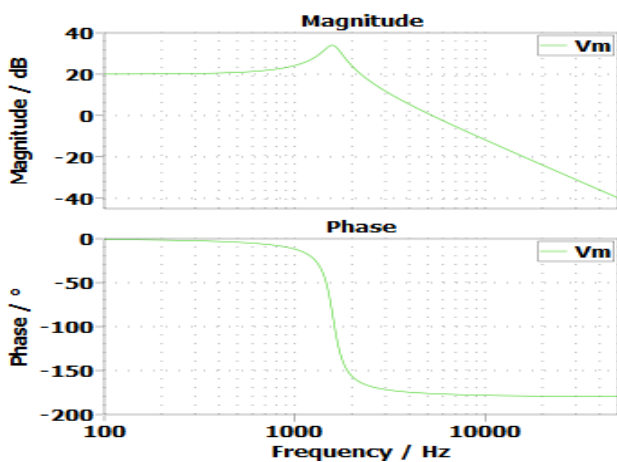


Fig.3. Bode Diagram

B. SMALL-SIGNAL TRANSFER FUNCTIONS EXTRACTION

- Using PLECS® the equivalent circuit is drawn and the Bode Diagram is extracted It does not give us algebraic transfer functions.

The resulting Bode Diagram is converted to MATLAB using the following steps:

- Clicking on the "File" menu,

- Click EXPORT, then CSV, and transfer the resulting graphics as a .csv file to MATLAB®.

A specific code is used to read the .csv file, showing us the Bode Diagram obtained in PLECS®.

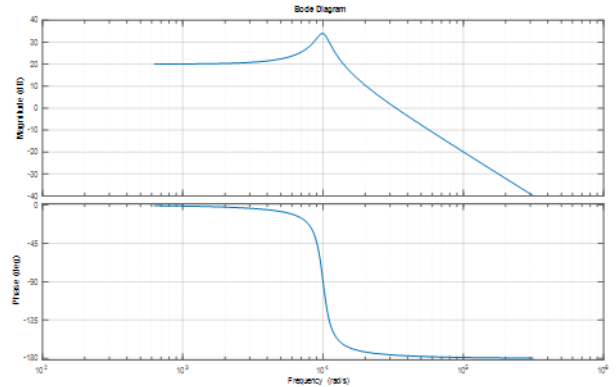


Fig. 4. shows the Bode Diagram resulting from the use of PLECS

By redrawing it with the mouse over Fig. 4 we get the curve of the Bode diagram obtained with PLECS® and MATLAB on top of each other as shown in Fig. 5 and then we get the small-signal transfer functions required for the resulting graph.

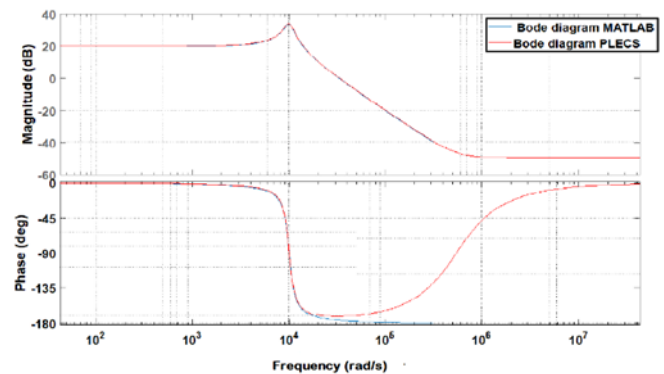


Fig 5. Shows the Bode diagrams resulting from the use of PLECS® and MATLAB

small-signal transfer functions required:

$$G(s) = \frac{0.002475 \times s^2 + 2146 \times s + 1.012 \times 10^9}{s^2 + 1996 \times s + 1.007 \times 10^8} \quad (1)$$

The resulting small-signal transfer functions $G(s)$ allow us to design a tight controller for the photovoltaic system

From the figure, it is easy to notice that the Bode diagram obtained from PLECS® Standalone and that obtained from MATLAB are identical in the radian/second frequency band. $[10^2, 10^4]$ Since

both start at 40 dB and drop to about -55 dB at higher volume, and both start at 0° to -180° at a lower gain, all this indicates the accuracy of a typical, small signal of a Buck converter designed with PLECS software.

V. CONCLUSION

PLECS® Standalone is a fast and easy-to-use simulation program that enables us to model converters, extract the Bode diagram of each converter, and extract its podcast diagram. and it allows us to extract the required small-signal transfer function, which helps us understand the behavior of the system and design a powerful closed-loop controller.

The obtained results proved the accuracy, speed, and ease of modeling, obtaining the Bode diagram and the transfer function, without falling into the calculation errors found in other methods

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