Current and Voltage Mode Control of DC-DC Converter in PSIM Environment

Gergana I. Vacheva and Nikolay L. Hinov
Department of Power Electronics, Faculty of Electronic Engineering and Technologies
Technical University of Sofia
8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria
{gergana_vacheva, hinov}@tu-sofia.bg

Abstract – **In the current paper a current mode control of a buck DC-DC converter is presented. The simulation model are realized in PSIM environment. The main purposes for this research is to present the program and her possibilities for simpler understanding and studying of basic principles of control design for the students and young researchers in Power electronics.**

Keywords – **current mode control; DC-DC converter; PSIM ; voltage mode control.**

I. INTRODUCTION

With the rates of development of modern technologies, the power electronics is significantly used. With the development of new environmental and energy-saving technologies, more and more important there are issues related to the efficient storage of electricity. Due to the innovative nature of the research and the severity of its consequences in case of unfavorable development of the operating modes, it is preferable for the simulation research to precede the operational one [2,3]. This requires research to be conducted using simulation models representing the characteristic properties of the elements and their relationships. This requires the creation of a mathematical algorithm, with the help of which in safe conditions to simulate and test the control modes of the power converters.

Simulation models give the most general idea of the content and nature of the problem. This allows to easily analyze the processes which are developed in them. Mathematical models can describe real physical objects with simple or detailed mathematical descriptions and algorithms. They are currently the most widespread, due to their indisputable advantages in terms of their applicability in structural approaches to the analysis of systems with a large number of different elements, of space-time constraints, their economic efficiency, requirements for small computational times, not requiring high computer power, the convenience of presenting the results, etc.

II. DESCRIPTION OF CONTROL SYSTEM AND PSIM ENVIRONMENT

In the current research a PI (proportional integral) control is used. This type of control is one of the basic strategies for current mode control [1]. The first application of a PI controller was for pneumatic devices, analog electronics and recently for microprocessors and digital devices.

Each control system is characterized by two main elements: a control unit and an object of regulation. The control system has the task to maintain a given input value of the object according to the desired regulation law. This quantity is affected by one or more disturbing influences, deviating it from its set value. The controller receives information about this value and by comparing it with its set value it generates the so-called regulating effect. The most commonly used means of regulating the dynamic and static characteristics of a control system is the introduction of feedback. It may cover one or more units of the management system. Negative feedback is most often used to improve the dynamics of the management process, which is why it is found in all management systems. An example of such a system is shown in Figure 1.

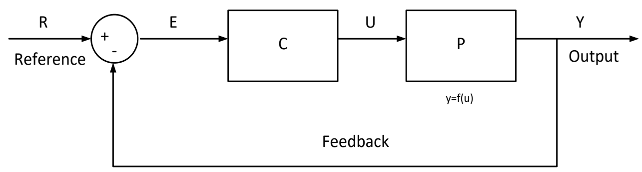

Fig. 1. Control system with negative feedback

In Figure 2 the view of a PI regulator in PSIM environment is presented. The basic value of the regulator such as the gain and the time constant are significantly simpler presented. That allows better understanding of the basic operations of control systems by the students and young researchers.

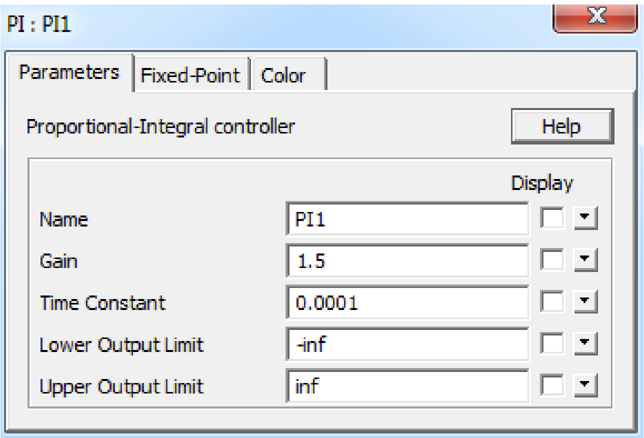

Fig. 2. View of the PI regulator in PSIM

III. CONTROL AND MODELING OF DC-DC CONVERTER

Figure 3 shows a block diagram describing current control. An additional internal circuit representing the current signal through the inductor has been added. The current signal converted to its voltage analogue is compared

978-1-7281-7426-6/20/$31.00 ©2020 IEEE

with the control voltage. This modification by replacing the triangular voltage with the current signal significantly changes the dynamic behavior of the converter. The converter takes into account some of the characteristics of the current source. The output current in the converter is equal to the average value of the current through the inductor or can be considered as a product of the average value of the output current and the duty cycle. In practical applications, a major disadvantage of this type of current-controlled regulator is the ability to read current peaks through the inductor instead of its average value [1].

Some of the advantages of using the current control method are: limiting the current peaks when switching and reducing the order of the equations in the dynamics of the converter. One of the main disadvantages of this type of control is the complex hardware, in which it is necessary to compensate the voltage control by a step signal to avoid the instability of the converter.

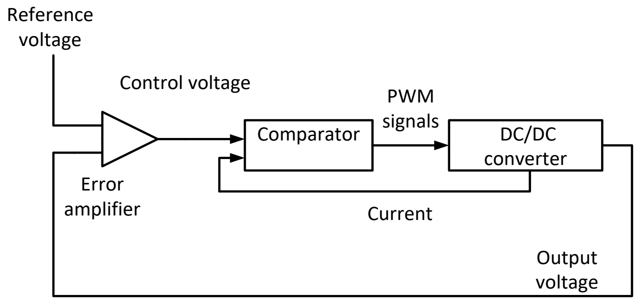

Fig. 3. Block scheme of current mode control

The main requirement is that the DC converter provides adjustable DC output voltage at AC load and input voltage. The values of the elements can also change with the change of time, temperature, etc. external factors. This requires the control of the output voltage to be realized through negative feedback. Two main methods for controlling this type of pulse-width modulation (PWM) converters are voltage and current control and are presented in Figure 3 and Figure 4, respectively.

In the voltage control method shown in Figure 4, the output voltage of the converter is compared to the reference and the deviation is input to an error amplifier. The unit that recalculates the error generates a controllable voltage signal that is compared to a triangular voltage of constant amplitude. The comparator creates PWM signals that are powered to control the switches in the DC converter. The duty cycle depends on the value of the controlled voltage. The frequency of the PWM signals is the same frequency as the triangular voltage. An important advantage of this type of control is the simplified hardware implementation and flexibility.

The error amplifier unit responds quickly to changes in the output voltage. For these reasons, voltage control provides good load regulation and control in case of changes in it. The regulation against changes in the input voltage (line regulation) can be delayed due to the fact that the output voltage must be regulated first and then the input voltage. To avoid this problem, the so-called "feedforward path" is added to the voltage control circuit. It directly affects the filling factor of the PWM, relative to the input voltage[1].

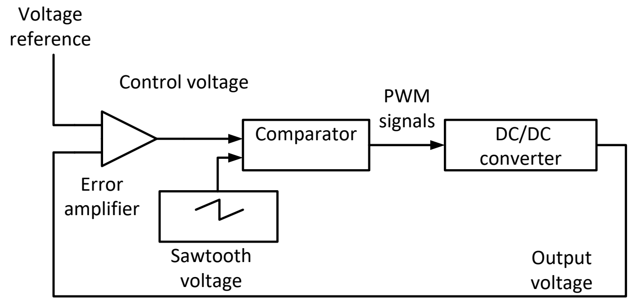

Fig. 4. Block scheme of voltage mode control

In Fig.5 the circuit diagram of a buck DC-DC converter is presented. The scheme consist of:

- V_s – DC voltage source;
- S – controlled switch;
- L – inductor;
- C – capacitor;
- D – diode;
- R – resistance.

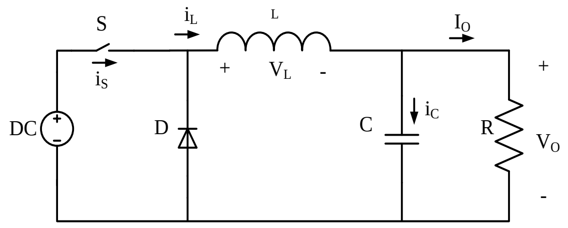

Fig. 5. Circuit diagram of DC-DC converter

The equation which describes the relation between the input and output voltage is:

$$(V_S - V_O)\cdot D\cdot T = -V_O\cdot(1-D)\cdot T \qquad (1)$$

Where V_O is the output voltage *and D* is the duty ratio.

IV. Mathematical modeling in PSIM Environment

A. *Current mode control*

In Figure 6 the model of the DC-DC buck converter with current mode control is presented. It consist of the step down converter, PI regulator and negative feedback by the current of the inductance.

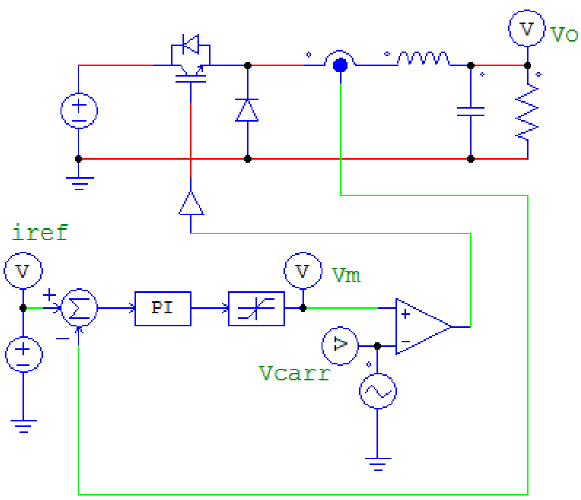

Fig. 6. Model of a buck converter with current mode control in PSIM

In Table 1 the main parameters used in the simulation model are presented.

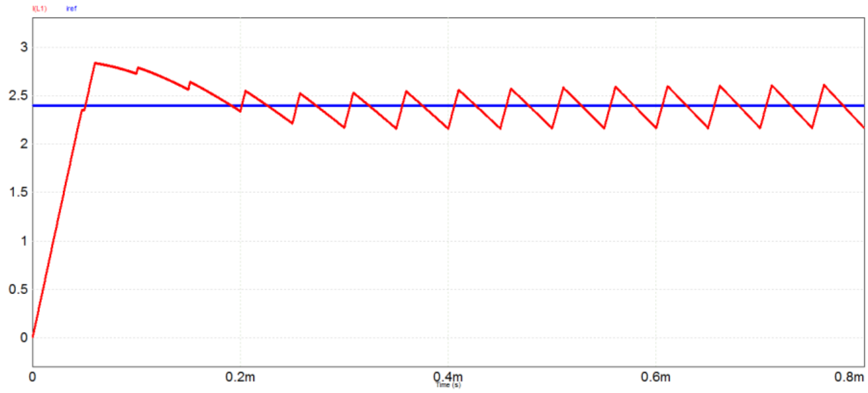

Fig. 8. Current of the inductance (red line) and reference current (blue line) with current mode control

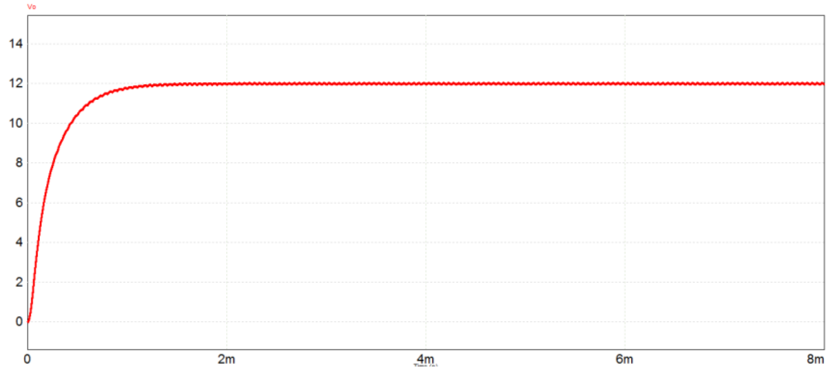

Fig. 9. Output voltage with current mode control

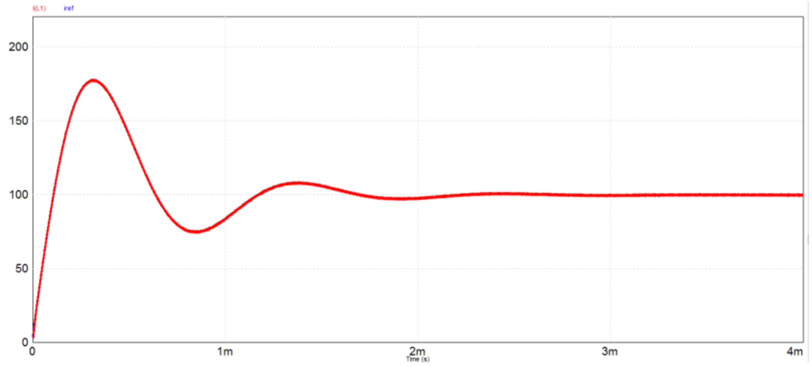

Fig. 10. Current of the inductance (red line) and reference current (blue line) with current and voltage mode control

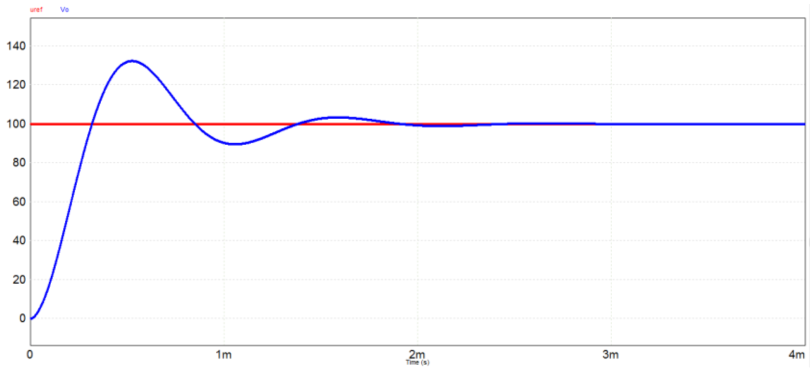

Fig. 11. Output voltage with current and voltage mode control

TABLE 1. PARAMETERS OF THE BUCK CONVERTER IN CURRENT MODE CONTROL

Load	R	5[Ω]
Input voltage	V_{DC}	50[V]
Output voltage	V_{out}	12[V]
Capacitance	C	47[μF]
Inductance	L	1[mH]

B. Current and voltage mode control

In Figure 7 the model of a buck converter with current and voltage control is presented. This scenario has additional loop for control the output voltage of the converter.

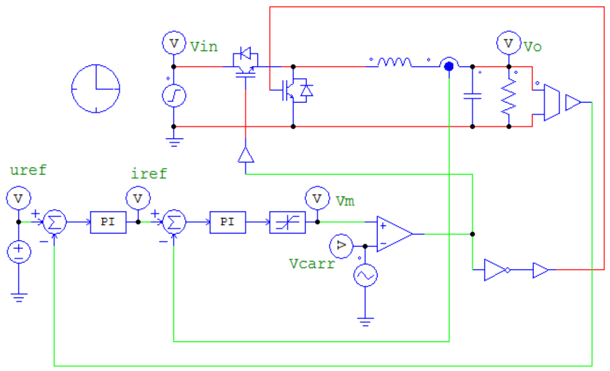

Fig. 7. Model of a buck converter with current and voltage mode control in PSIM

In Table 2 the main parameters used in the simulation model are presented.

TABLE 2. PARAMETERS OF THE BUCK CONVERTER IN VOLTAGE MODE CONTROL

Load	R	1[Ω]
Input voltage	V_{DC}	250[V]
Output voltage	V_{out}	100[V]
Capacitance	C	245[μF]
Inductance	L	200[μH]

V. RESULTS

In the following figure from 8 to 11 the simulations results from the realized model are presented. The first two shows the curve of the current of the inductance and the output voltage with the current mode control.

The second two respectively shows the current and the voltage with the voltage mode control.

VI. CONCLUSION

In this research a mathematical model with current and voltage mode control of buck DC-DC converter are presented. The simulation results are realized in PSIM environment. The basic principles for control of DC-DC converter in this software are presented. The main purposes for this study is to facilitate the students and young researches for better understanding of methods for design control.

In this cases the PI regulators are properly set and execute the reference values. It is used different parameters for the simulation but the results shows that the models operates properly.

This type of research could be implemented for educational purposes in disciplines such as Power electronics, industrial electronics and etc.

ACKNOWLEDGMENT

This work was supported by the European Regional Development Fund within the Operational Programme “Science and Education for Smart Growth 2014 - 2020” under the Project CoE “National center of mechatronics and clean technologies“ BG05M2OP001-1.001-0008.

REFERENCES

[1] Muhammad H. Rashid, Power electronics handbook: devices, circuits, and applications handbook, 3rd ed., ISBN 978-0-12-382036-5

[2] Jose Rodriguez, Patricio Cortes, Predictive control of power converters and electrical drives, John Wiley & Sons, Ltd., 2012.

[3] N. Mohan, T.M. Undeland, and W. P. Robbins, Power electronics, 3rd ed. John Wiley & Sons, Inc., 2003.

[4] Ogata K., Modern Control Engeneering, Prentice Hall, 2002.

[5] J. Holtz, “Pulsewidth modulation electronic power conversion,” Proceedings of the IEEE, vol.82, no. 8, pp. 1194-1214, August 1994.

[6] M. P. Kazmierkowski, R. Krishnan, and F. Blaabjerg, Control in power electronics. Academic Press, 2002.

[7] N. Mutoh and T. Inoue, "A control method to charge series-connected ultraelectric double-layer capacitors suitable for photovoltaic generation systems combining mppt control method", IEEE Trans. Ind. Electron., vol. 54, no. 1, pp. 374-383, 2007

[8] R. W. Erickson and D. Maksimovic , Fundamentals of Power Electronics, 2001, Kluwer

[9] D. W. Hart,Introduction to Power Electronics, Englewood Cliffs, NJ: Prentice Hall, 1997.

[10] P. T. Krein, Elements of Power Electronics, New York: Oxford University Press, 1998.

[11] A. I. Pressman,Switching Power Supply Design, 2nd Ed., New York: McGraw-Hill, 1998.

[12] A. M. Trzynadlowski, Introduction to Modern Power Electronics, New York: Wiley Interscience, 1998