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DIFFERENT MATHEMATICAL MODEL FOR THE CHOPPER CIRCUIT

DRUKČIJI MATEMATIČKI MODEL ZA SKLOP TRANZISTORSKOG PRETVARAČA (CHOPPER-A)

Erol Can, H. Hüseyin Sayan

Original scientific paper

Abstract: *In this study, dc-dc boost converter circuit is described as transformer circuit for direct form of energy in the electrical machine driver system of electrical and electronic engineering. First, mathematical equations of the converter circuit are created when circuit switch opened and closed controlling two states. Then, the equations are resolved for common equation so that the state space equation is formed in matrix form. A mathematical model of the converter circuit is performed at the Matlab Simulink.*

Keywords: *DC-DC boost converter, new mathematical model, transformer circuits*

Izvorni znanstveni rad

Sažetak: *U ovom istraživanju opisan je sklop istosmjernog uzlaznog pretvarača kao transformatorski sklop za izravne oblike energije u vozačkom sustavu električnog motora u elektrotehnici i elektronici. Prvo su kreirane matematičke jednadžbe sklopa pretvarača, a sklopka sklopa otvaranjem i zatvaranjem kontrolira dva stanja. Zatim su riješene jednadžbe za opću jednadžbu tako što je jednadžba prostora stanja formirana u matričnom obliku. Matematički model stvorenog pretvarača sklopa izveden je u Matlab Simulink.*

Ključne riječi: *DC-DC uzlazni pretvarač, novi matematički model, transformatorski sklopovi*

1. INTRODUCTION

Nowadays, renewable sources of energy are focused so that increasing energy needs can be tolerated [1-3]. Since renewable and DC sources are also converted for some driver circuits, motors and some loads can be driven [10]. Therefore, power electronic circuits were used to convert electric energy for loads driven in scientific articles [11]-[12]. In addition, industry and some workspaces have not worked with known transformer circuits which are not regulating DC (direct current) current. DC-DC converter circuits in power electronic applications can be used to the direct current motor for control of the direct current source [5]. In this study, steady state equation of the boost converter has been created. The equation is unlike the other applied scientific studies [4-8]. Mathematical equations of the converter circuit are created according to the circuit switches opened and closed that control two states. Then, the equations are resolved for common equation so that steady space equation can be formed in matrix form. When a new mathematical model of the converter circuit is performed at the Matlab Simulink, optimal result can be achieved for power electronic circuits.

2. BOOST CONVERTER CIRCUIT DESIGN

DC-DC boost converter given in Fig. 1 is used to increase from low voltages to high voltages. The converter circuit mathematical model is demonstrated for the relationship between equations of input and output voltages. In the equations, V_g is input voltage, V_L is inductance voltage, and i_L is inductance current, R is resistive load, C is capacitor for converter output voltage and D is duty time for switches, I_z is the skill of the converter to load change.

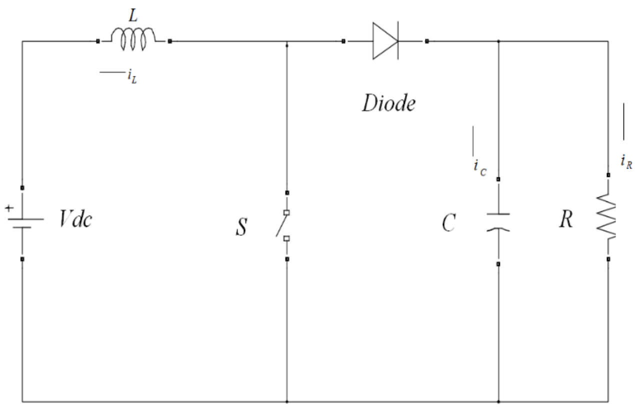

Figure 1. Boost converter circuit model

The pulse width modulation signal is applied to *S* that is switch of converter circuit as shown in Fig. 1. *DT* time shows the switching time is ON. (*(1-D) T)* time indicates switching time is OFF as shown in Fig. 2.

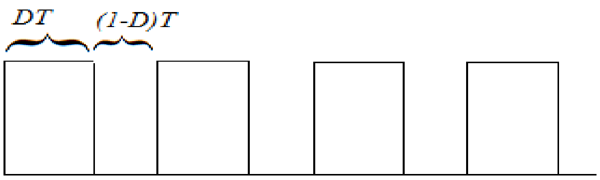

Figure 2. Pulse width modulation according to switching time.

The boost converter circuit equations are generally founded as follows:

$$Vg = VL = Vdc \tag{1}$$

$$\frac{di_L}{dt} L = Vg \tag{2}$$

$$\frac{di_L}{dt} = \frac{Vg}{L} \tag{3}$$

$$I_{max} - I_{min} = (\frac{Vg}{L})DT \tag{4}$$

$$Vg = VL + Vc \tag{5}$$

$$\frac{di_L}{dt} L = Vg - Vc \tag{6}$$

$$\frac{di_L}{dt} = \frac{Vg - Vc}{L} \tag{7}$$

$$I_{min} - I_{max} = (\frac{Vg - Vc}{L})(1 - D)T \tag{8}$$

$$(\frac{Vg - Vc}{L})(1 - D)T = -(\frac{Vg}{L})DT \tag{9}$$

$$Vc = (\frac{Vg}{1 - D}) \tag{10}$$

The equations of inductance current and output voltage have to be formed as $x = Ax + Bu$ for steady space.

For *S* = ON

$$Vg = VL \tag{11}$$

$$\frac{di_L}{dt} L = Vg \tag{12}$$

$$i_L = \frac{Vg}{L} \tag{13}$$

$$\dot{V} = \frac{I_Z}{C} \tag{14}$$

Variables obtained in the above equations are shown in matrix form as Eq. (15).

$$\begin{bmatrix} i \\ \dot{V} \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}}_{DA_{on}} \cdot \begin{bmatrix} I \\ V \end{bmatrix} + \underbrace{\begin{bmatrix} \frac{D}{L} & 0 \\ 0 & \frac{D}{C} \end{bmatrix}}_{DB_{on}} \cdot \begin{bmatrix} V_g \\ I_Z \end{bmatrix} \tag{15}$$

For *S* = OFF

$$Vg = VL + Vc \tag{16}$$

$$\frac{di_L}{dt} L = Vg - Vc \tag{17}$$

$$\frac{di_L}{dt} = \frac{Vg - Vc}{L} \tag{18}$$

$$i = \frac{Vg}{L} - \frac{Vc}{L} \tag{19}$$

$$\dot{V} = (I - \frac{V}{R} + I_z) \cdot \frac{1}{C} \tag{20}$$

$$\dot{V} = \frac{I}{C} - \frac{V}{RC} + I_Z \frac{1}{C} \tag{21}$$

$$\begin{bmatrix} i \\ \dot{V} \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & -\frac{1}{C} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix}}_{(1-D)A_{off}} \cdot \begin{bmatrix} I \\ V \end{bmatrix} + \underbrace{\begin{bmatrix} 0 & 0 \\ 0 & \frac{1}{C} \end{bmatrix}}_{(1-D)B_{off}} \cdot \begin{bmatrix} V_g \\ I_Z \end{bmatrix} \tag{22}$$

A and B are created to form a common state space equation which has variables for converter circuit as given in Eq. (23) and Eq. (24).

$$A = DA_{on} + (1-D)A_{off} \tag{23}$$

$$B = DB_{on} + (1-D)B_{off} \tag{24}$$

Finally, matrix form is given as below:

$$A = (D-1)\begin{bmatrix} 0 & -\frac{1}{L} \\ -\frac{1}{C} & -\frac{1}{RC} \end{bmatrix} \quad B = \begin{bmatrix} \frac{D}{L} & 0 \\ 0 & \frac{1}{C} \end{bmatrix} \tag{25}$$

2.1. Simulation experimentation

After the mathematical models are formed, created matrix form of the converter circuit is performed. Then, converter circuit is performed at the Matlab Simulink as shown in Fig. 3.

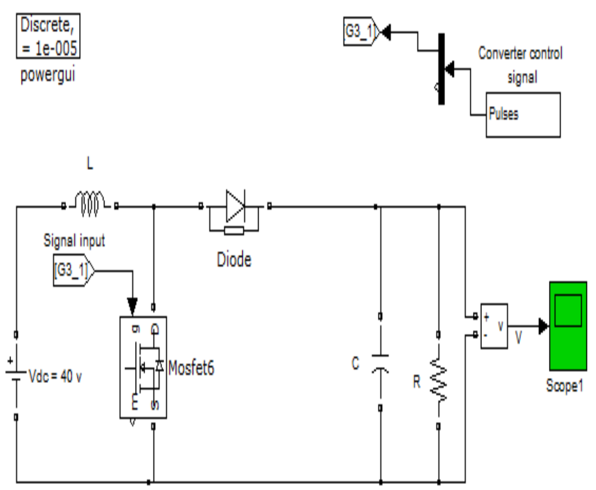

Figure 3. Boost converter in Matlab Simulink model

When 40 volt of direct voltage is applied to converter of input, the output voltage of the converter circuit increases 400 volt on output of the boost converter for 0.9 value of duty cycle as shown in Fig. 4.

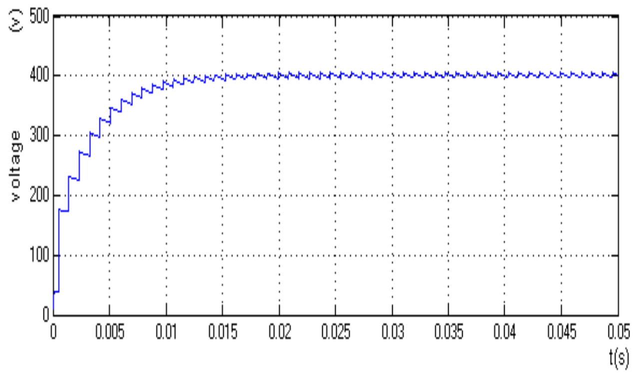

Figure 4. The simulated boost converter output voltage

3. RESULTS

A new mathematical model of the boost converter circuit is calculated so that models can be examined in the study. In general, the mathematical models are formed with duty time. Two considered situations are created in order to create different mathematical model and the matrix form. After creating mathematical model, the effect of the output voltage equation which is *(Vg/ (1-D))* is observed on the circuit of the output voltage when simulation is performed according to input voltage (*Vg*). 40 volt of input voltage can be increased to 400 volt of output voltage with for 0.9 value of duty cycle. New mathematical model using converter achieves that input voltage is boosted as 1x10.

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Authors` contacts:

Dr. Erol Can
Erzincan University, School of Civil Aviation,
Department of Aircraft Airframe and Powerplant,
Erzincan,Turkey
E-mail: can_e@hotmail.com

H. Hüseyin Sayan
Gazi University, Faculty of Technology,
Department of Electrical and Electronics
Engineering, Ankara, Turkey
E-mail: hsayan@gazi.edu.tr