DIFFERENT MATHEMATICAL MODEL FOR THE CHOPPER CIRCUIT

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

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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

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.

\[ DT \quad (1-D)T \]

**Figure 2.** Pulse width modulation according to switching time.

The boost converter circuit equations are generally founded as follows:

\[ i = \frac{V_g - V_c}{L} \quad (19) \]

\[ V_c = \frac{V_g}{1-D} \quad (10) \]

\[ V_g = VL \quad (11) \]

\[ \frac{di}{dt} = \frac{V_g}{L} \quad (12) \]

\[ i_L = \frac{V_g}{L} \quad (13) \]

\[ \dot{V} = \frac{I_Z}{C} \quad (14) \]

\[ V_g = VL + V_c \quad (16) \]

\[ \frac{di_L}{dt} = \frac{V_g - V_c}{L} \quad (17) \]

\[ \frac{di_L}{dt} = \frac{V_g - V_c}{L} \quad (18) \]

\[ V_g = VL \quad (1) \]

\[ \frac{di}{dt} = \frac{V_g}{L} \quad (2) \]

\[ di = \frac{V_g}{L} \quad (3) \]

\[ i_{max} - i_{min} = \frac{V_g}{L}(1-T) \quad (4) \]

\[ V_g = VL + V_c \quad (5) \]

\[ \frac{di}{dt} = \frac{V_g - V_c}{L} \quad (6) \]

\[ i_{min} - i_{max} = \frac{V_g - V_c}{L}((1-D)T) \quad (8) \]

\[ \frac{V_g - V_c}{L}((1-D)T) = -\frac{V_g}{L}(1-\frac{V_g}{V_c}) \quad (9) \]

\[ V_c = \frac{V_g}{1-D} \quad (10) \]

\[ \dot{V} = \frac{I - \frac{V}{R} + I_Z}{RC} \frac{1}{C} \quad (20) \]

\[ \dot{V} = \frac{I}{C} - \frac{V}{RC} + I_Z \frac{1}{C} \quad (21) \]

\[ \frac{\dot{i}}{\dot{V}} = \left[ \begin{array}{c} 0 \\ \frac{1}{C} \\ \frac{1}{RC} \\ (1-D)A_{off} \end{array} \right] \left[ \begin{array}{c} I \\ V \\ 0 \end{array} \right] + \left[ \begin{array}{c} 0 \\ 0 \end{array} \right] \left[ \begin{array}{c} V_g \\ I_Z \end{array} \right] \quad (22) \]

\[ \frac{\dot{i}}{\dot{V}} = \left[ \begin{array}{c} 0 \\ \frac{1}{C} \\ \frac{1}{RC} \\ (1-D)B_{off} \end{array} \right] \left[ \begin{array}{c} I \\ V \\ 0 \end{array} \right] + \left[ \begin{array}{c} 0 \\ 0 \end{array} \right] \left[ \begin{array}{c} V_g \\ I_Z \end{array} \right] \quad (22) \]

\[ A = DA_{on} + (1-D)A_{off} \quad (23) \]

\[ B = DB_{on} + (1-D)B_{off} \quad (24) \]

Finally, matrix form is given as below:

\[ A = (D - 1) \left[ \begin{array}{ccc} 0 & -\frac{1}{L} & 0 \\ \frac{1}{C} & -\frac{1}{RC} & 0 \end{array} \right] \cdot B = \left[ \begin{array}{ccc} \frac{D}{L} & 0 \\ -\frac{1}{C} & -\frac{1}{RC} \end{array} \right] \cdot \left[ \begin{array}{c} 0 \\ 1 \end{array} \right] \quad (25) \]

### 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.
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 3. Boost converter in Matlab Simulink model](image)

![Figure 4. The simulated boost converter output voltage](image)

**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 \((V_g/(1-D))\) is observed on the circuit of the output voltage when simulation is performed according to input voltage \((V_g)\). 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.

**4. REFERENCES**


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