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Influence of Elemental Parameter in the Boost And the Buck Converter

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Abstract--**Nowadays, thanks to the great advances in energy technology, renewable energy has grown and become an indispensable part of the power system. However, the dependence on the natural elements of this form of energy causes the output parameters to become unstable: voltage, power, etc. Therefore, the integration of DC-DC power converters becomes necessary to meet voltage stability and conversion efficiency. This paper investigates the effect of elements in the Boost and Buck DC / DC converters by using Pulse Width Modulation (PWM) control method. The method of calculating the circuit element is given, results indicate the advantages and disadvantages of the circuit when operating with different sets of parameters and the stability of the converter.**

Keywords--Boost converter; Buck converter; DC/DC power converter; Elemental parameter; Renewable energy; PWM;

I. INTRODUCTION

Currently, 152 countries are members of the International Renewable Energy Agency (IRENA), and 28 countries are in the process of admission. Renewable energy sources are gaining more attention that gradually replace traditional forms of energy. This is a leading solution to produce more power while other sources of energy cannot meet the demand due to the decline in fossil fuels and environmental problems. However, those type of energies are influenced and dependent on natural conditions: the obscure [1], wind speed, etc., which cause some problems of voltage instability. Therefore, energy converters should be used to ensure system stability [2].

The development of technology in the field of renewable energy makes solar power and wind power become the fastest development in different types of renewable energy. This makes DC/DC converters even more essential. These converters operate depending on two main factors: the on-off time of the semiconductor valve (T_{on}-T_{off}) in a cycle (T) (or the switching frequency f_s); exchanges in the process of accumulation and release of energy between inductors and capacitors. In addition, studies [3-5] show that parasitic resistor components cause loss and affect operation of the circuit.

However, some previous studies do not show clearly the level influence of those elements. Therefore, this paper presents a method to calculate parameters of the circuit in combination with simulating in Matlab/Simulink software, which shows clearly the response as well as the stability of the output voltage when changing the parameters. DC/DC converters incorporate PWM in combination with changing the set of parameters in the circuit for the purpose of optimizing the output voltage of the circuit with the highest conversion efficiency. The results show that the alternatives have some disadvantages, overshoot of the output voltage and steady time are quite large. Therefore, the choice of parameters is only relative. Methods and control algorithms need to be studied, developed and further integrated.

II. DESIGN AND CALCULATION OF THE DC/DC CONVERTER

A. Boost converter

Boost converters are supplied by a DC power source that can be battery, solar panel, AC/DC converters in wind power systems, etc. In the closed state of the semiconductor valve (T_{on}), the circuit consists only the source, inductors, IGBT Switch (or MOSFET). At this time, the current through the inductor is increasing very fast, the inductor accumulates power and through the semiconductor valve. At the same time, the capacitor acts as a DC source, discharging the power supply to the load. When the semiconductor valve is open (T_{off}), the inductors appears V_L. The input voltage V_{in} and the voltage at the inductor V_L passes the diode to supply for the load and charge the capacitor. Then, the output voltage will be greater than the input voltage. The output voltage depends on the opening-closing time of the valve in the control circuit with pulse width modulation (PWM). The figure 1 shows the diagram of the boost converter. The output voltage is calculated according to the following formula:

$$V_o = \frac{V_i}{1-D} = \frac{V_i}{\gamma} \qquad (1)$$

With Conversion factor is calculated by the formula:

$$D = \frac{T_{on}}{T} = 1 - \frac{V_i}{V_o} \qquad (2)$$

$$\text{or} \quad \gamma = 1 - D = \frac{T_{off}}{T} \qquad (3)$$

Where: V_i is the input voltage, V_o is the output voltage, D is the conversion factor, γ is harsh pulse ratio. Due to the change of the D factor of the semiconductor valves, we can flexibly vary the output voltage value of the circuit as required by the load.

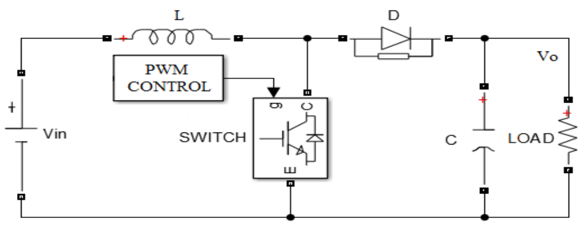

Fig. 1. The diagram of the Boost Converter.

B. Buck converter

Basically, the elements are like the Boost converter. The figure 2 shows the general circuit diagram. In the closed state of the lock, the circuit includes source, IGBT, inductor, capacitor and load. The current flows through the inductance L. Then, the lock switches to the open state, the circuit uses the energy stored in the inductor L during the transition to continue providing the load during closing time. Then, the lock switches to the open state, the circuit uses the energy stored in the inductor L during the transition to continue providing the load during closing time. Conversion factor is calculated by the formula:

$$D = \frac{T_{on}}{T} \qquad (4)$$

The output voltage is calculated according to the following formula:

$$V_o = V_i \times D \qquad (5)$$

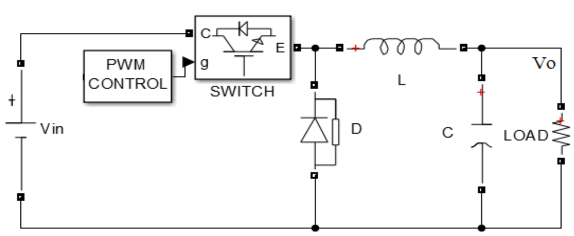

Fig. 2. The diagram of the Buck Converter.

C. Calculation

The input voltage limit V_{in}, the output voltage limit V_{out}, maximal current of load I_{outmax}, voltage fluctuation ΔV, current fluctuation ΔI and switching frequency f_s is the condition for calculating the design parameters of a DC/DC converter circuit. For the selection of IGBT or MOSFET semiconductor valves, the manufacturers provide a datasheet for max working voltage V_{max}, the max working current I_{max}, and rated operating frequency of valves. These semiconductor valves have very high f_s that can up to tens of thousands or hundreds of thousands of hertz (Hz). Based on the above conditions, the inductance of the inductor and the capacitance of the capacitor are determined by the formulas [6-9] summarized in Table 1. However, this is a limited condition in choosing the value of the elements in the circuit. This is not a standard condition for the circuit to function properly. Therefore, the circuit is not optimized.

TABLE 1. CALCULATION FORMULA ELEMETAL CIRCUIT.

Type	Boost Converter	Buck Converter
Inductor Selection (H)	$L = \frac{(V_{out}-V_{in})}{\Delta I_L \times f_s}$ (6)	$L = \frac{V_{out}\times(V_{in}-out)}{\Delta I_L \times f_s \times V_{in}}$ (9)
Minimum Capacitor Selection (F)	$C_{out} = \frac{I_{out(max)}\times D}{f_S \times \Delta V_{out}}$ (7)	$C_{out} = \frac{\Delta I_L}{8 \times f_S \times \Delta V_{out}}$ (10)
Maximum Switch Current (A)	$I_{sw} = \frac{\Delta I_L}{2} + \frac{I_{out(max)}}{1-D}$ (8)	$I_{sw} = \frac{\Delta I_L}{2} + I_{out(max)}$ (11)

Where: ΔI_L is the current fluctuation in the inductor that is usually selected between 20% -40% of the load current; f_s is the working frequency (on-off frequency) of the semiconductor valve; ΔV_{out} is the output voltage fluctuation.

The maximum switch current (I_{sw}) is the largest working current that semiconductor valves can withstand. Normally, when the circuit is operating, there may be cases of sudden increase in current (motor starting current, variable load, overvoltage), which may cause the semiconductor valve to overheat and deteriorate. Therefore, I_{sw} is calculated and selected greater than the I_{outmax} value to ensure the stable operation of the circuit and protect the semiconductor valve.

In addition to the switching frequency of the valve, a resonant frequency f_0 exists in the circuit due to the energy exchange between the inductance and the capacitor causing:

$$f_0 = \frac{1}{2\pi\sqrt{L \times C}} \qquad (12)$$

D. PWM Controller method

PWM - Pulse Width Modulation is the modulation based on the change in the pulse width of the pulse, resulting in a change in the output voltage, which is carried out according to the principle of periodically closing and closing according to the time correction law with an executive element is the IGBT (or MOSFET) semiconductor valve. In the converter power electronics, this is the method commonly used as it can control easily, while ensuring high accuracy [9-12]. A PWM signal is produced by comparing a reference signal r(t) with a carrier signal c(t) that is well understood in the document [13]. Pulses are modulated in a variety of ways, thanks to specialized circuits or software, binary PWM output is described by the following general formula:

$$b_{PWM}(t) = sgn[r(t) - c(t)] \tag{13}$$

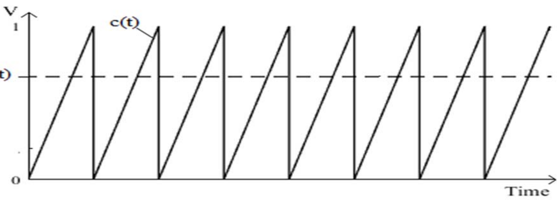

Fig. 3. Sign of r(t) and c(t).

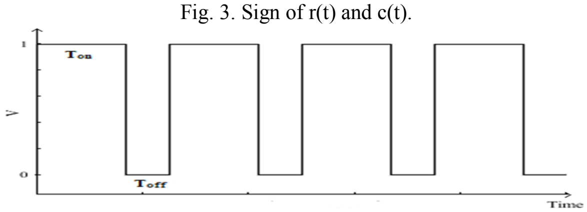

Fig. 4. PWM Signal.

III. SIMULATION AND RESULTS

A. Boost Converter

Design a Boost converter circuit: V_{in}=48V, V_{out}=220V; D=0.782; R=200 Ohm; f_s=40kHz. We choose the following circuit parameters: C=40μF, L=50mH, I_{sw}=5.1A, f_0=112Hz based on formulas (6), (7), (8), (12) in Table 1. We obtain the results as shown in the figure 5.

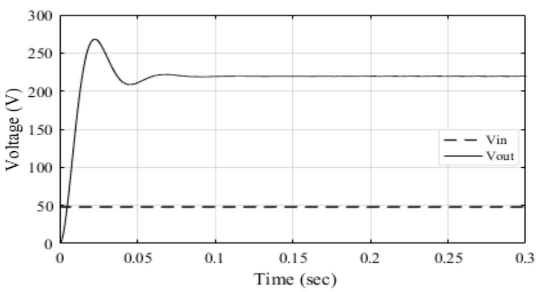

Fig. 5. The Output Voltage of Boost Converter.

With the selection of circuit elements as above, the output voltage has a large number of oscillations, the overshoot voltage reaches 266.4V, up 22% in comparison with the reference voltage 220V. With such an output voltage response, the circuit can be damaged if the components are not capable of resisting high voltage.

To reduce the overshoot at the same time analyze the influence of the elemental parameters on the output voltage of the circuit, we change the parameters L and C to satisfy the fast steady time conditions and the low overshoot voltage. The value of L is changed to 50mH, 100mH, 200mH, 300mH corresponding to the frequencies f_0 100Hz, 80Hz, 60Hz, 40Hz. Based on the equation (12), the values of C can be calculated corresponding to the output V_{01}, V_{02}, V_{03}, V_{04}. The responses from the figure 6 show that the higher the frequency f_0, the greater the output overshoot voltage, the faster steady time and vice versa.

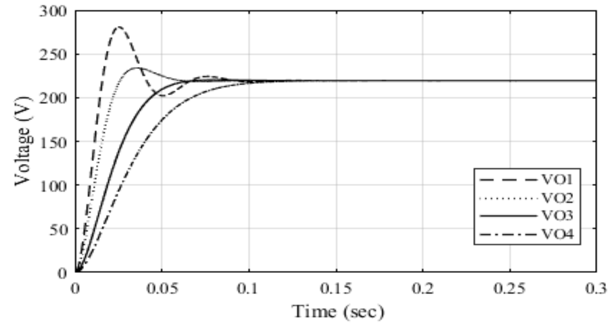

Fig. 6. The Output voltage of Boost Converter when parameter changes.

With low f_0 case with L=200mH (V_{03}) and 300mH (V_{04}), there is almost no overshoot phenomenon but the steady time is long. It is clearly to see that in the case of L=300mH, the circuit needs 0.15s to reach the steady region. Meanwhile, with the values L=50mH (V_{01}) and L=100mH (V_{02}), the output overshoot voltage is quite clear (281V and 234V respectively) but only about 0.1s that the circuit has reached the steady region.

B. Buck Converter

Like Boost Converter, Buck Converter is designed with parameters: V_{in}=690V; V_{out}=220V; D=0.32; R=200 Ohm; f_s=40kHz. We choose the following circuit parameters: C=1.5μF, L=50mH, I_{sw}=1.2A, f_0=581Hz based on formulas (9, (10), (11), (12) in Table 1. We obtain the results as shown in the figure 7.

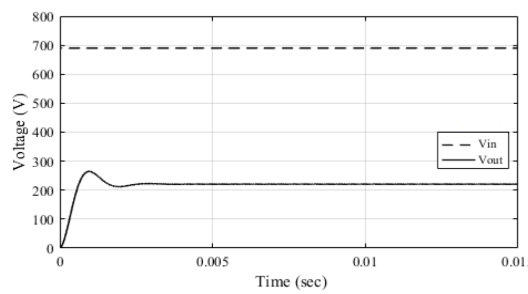

Fig. 7. The Output Voltage of Buck Converter.

The results are similar to Boost Converter. The output overshoot voltage is up to 264.6V (exceeds 26%). Again, the right parameters should be selected so that the output overshoot can be reduced but there is still ensured the quick steady time. The value of L is the same as in the case of the Boost converter with frequencies f_0: 500Hz, 400Hz, 300Hz, 200Hz. The output voltage response is shown in the figure 8. At high level of resonant frequency, L=50mH (V_{01}) and L=100mH (V_{02}), the overshoot phenomenon is similar to the case of Boost Converter, the overshoot voltage reaches 277V and 238V. Meanwhile, with low f_0 for the case of L=200mH (V_{03}) and L=300mH (V_{04}), there is almost no overshoot but the steady time is longer than the other case.

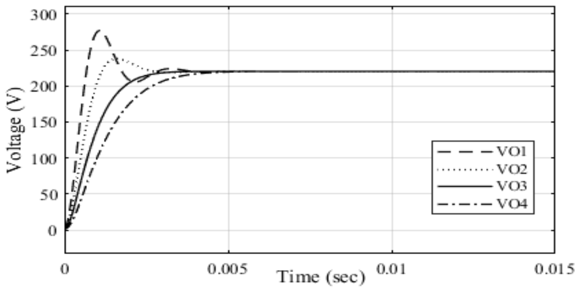

Fig. 8. The Output voltage of Buck Converter when parameter changes.

C. Discussion

From the simulated cases above, the operating parameters of the two circuits are summarized in tables 2 and 3 below.

TABLE 2. OPERATION PARAMETERS OF BOOST CONVERTER.

Inductor L (mH)	50	100	200	300
Capacitor C (µF)	53	35	40	50
Rising time (ms)	10.48	16.93	35.278	53.253
Overshoot (%)	29.2	6.99	0.505	0
Reference voltage (V)	220			
Output Voltage (V)	219.4	219.4	219.4	219.4

TABLE 3. OPERATION PARAMETERS OF BUCK CONVERTER.

Inductor L (mH)	50	100	200	300
Capacitor C (µF)	2	1.6	1.4	2.1
Rising time (ms)	0.36	0.67	1.49	2.23
Overshoot (%)	25.8	8.1	0.505	0
Reference voltage (V)	220			
Output Voltage (V)	220.2	220.2	220.2	220.2

From the parameter table can be seen the operation and output voltage of the circuit greatly depends on the selection of parameters L and C. The energy exchange of the two elements generates a resonant frequency that greatly affects the steady ability of the circuit. In all cases, the resonant frequency f_0 decreases, the output overshoot voltage is markedly reduced but the time increases and the steady time is much larger. Hence, the time responses are transient time, steady time which depends on the choice of L and C. From the simulated cases, the V_{03} voltage response of both circuits may be the best choice, there is almost no overshoot phenomenon, the time increase on the average level. There is no option of selecting element parameters that satisfy both the lowest overshoot and the fastest steady time.

IV. CONCLUSION

The selection of component parts greatly influences overshoot voltage, voltage fluctuations, current fluctuations and the steady time of the circuit. The changing the values of L and C creates different f_0 frequencies; higher the f_0 value, faster the circuit goes to the steady value, but at the same time it causes a higher overshoot, which can be shown in Tables 2 and 3. Equations are only relative in the selection of element parameters. Consequently, it is necessary to know the load requirements in order to calculate and select the appropriate parameters based on the manufacturer's datasheet.

However, this paper studies only the operation of DC/DC converters with constant input voltage and D-factor. Therefore, it is necessary to have additional studies of integrated controllers as well as control methods for the circuit to meet the voltage requirements: keeping the output voltage constant when the input voltage is fluctuated or adjusting the output voltage suitable with the load.

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