



# Control of High Voltage Boost Converter for High Voltage Application

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**ABSTRACT:** In this paper, high voltage-boosting converters are presented. High step-up converter have been widely used in the industry. One of the application of high voltage boost converters the DC/DC front end converter used in network and telecommunication industry. DC/DC front end converter convert 48V DC supply from battery plant to 360V DC. The high voltage boost converters are constructed based on bootstrap capacitors and boost inductors. The converters are based on the fact that the number of inductors is increased, and these inductors are connected in series during the demagnetizing period, thereby pumping the energy created by the input voltage and the energy stored in the inductors into the output terminal to obtain the high voltage conversion ratio. Modified boost converter was proposed which has higher conversion ratio than conventional boost converter. By changing the switching strategy, two different conversion ratio can be obtained. Therefore, the proposed converters can be used according to industrial applications.

**KEYWORDS:** Boost converter, bootstrap capacitor, boosting inductor, voltage-boosting converter, voltage conversion ratio, DC/DC front end converter, telecommunication and network industry.

## I. INTRODUCTION

High step-up converters have been widely used in the industry. The application of converters are uninterruptible power supply, and solar cell system, intensity discharge lamp driver [1], [2], etc. These high voltage boost converters are based on traditional boost converter or flyback converter. The flyback converter has high conversion ratio. But its corresponding leakage inductance is very high. The conversion ratio of flyback converter is  $\frac{D}{1-D} \times \frac{N_2}{N_1}$ . Boost converter has simple structure. The voltage conversion ratio of boost converter is not so high. The conversion ratio of boost converter is  $\frac{D}{1-D}$ .

DC/DC front end converter is one of the application high voltage boost converter which is used in telecommunication and network industries. The telecom industry uses a 48 V bus distributed power system, which is backed up by a 48V dc battery plant. It provides many hours of reserve time. A high voltage boost converter is required in DC/DC front end converter with high voltage conversion gain. The converter boost the 48 V to about 360V which is the required DC bus voltage for the functioning of telecommunication and network industry.

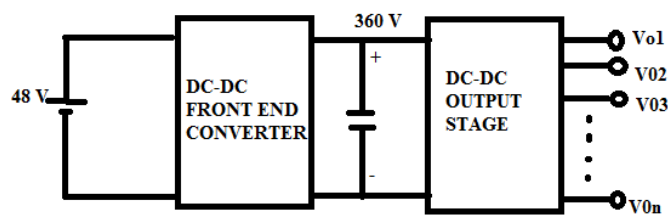


Figure 1. Block diagram of computer power supplies for networking applications

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There are many high voltage converters. One of the method of improving the voltage conversion ratio is explained in [3] ,[4]. In this method the number of inductors are increased . These inductors are connected in series during the demagnetizing period .It pumps the energy created by the input voltage and the stored energy inthe inductors into the output terminal and thereby high voltage conversion ratio is achieved. In this method the current in each inductor can be considered as a current source. But when the inductors are connected in series, it imply that inductors with different values are connected in series. In the method [5]–[8], by using coupling inductors high voltage conversion ratio are achieved. But in this method ,voltage spikes due to accompanying leakage inductance are more. Another method which is explained in [9]-[11] has simple operation but its corresponding voltage conversion ratio is too low. Voltage lift technique is used to boost the output voltage[12] and [13]. But in this method the voltage conversion ratios are not high enough.The voltage conversion ratios can improved by increasing the number of voltage-boosting cells[14],[15]. But in this method additional components or floating active switches are required and the overall circuits are complicated and would require the corresponding isolated drivers.

In order to improve the voltage conversion ratio a high voltage boost converter was proposed. The converter is based on two bootstrap capacitors and two inductors. The two inductors are connected in series during the demagnetizing period

## II. HIGH VOLTAGE BOOST CONVERTER BASED ON BOOTSTRAP CAPACITORS AND BOOST INDUCTORS

The high voltage boost converter contains five MOSFET switches  $S_1$  ,  $S_2$ ,  $S_3$ ,  $S_4$ and  $S_5$  , three bootstrap capacitors  $C_{b1}$  ,  $C_{b2}$  and  $C_e$ , one output diode  $D_o$ , two inductors  $L_1$  and  $L_2$ , four bootstrap diodes  $D_{b1}$  ,  $D_{b2}$  ,  $D_1$  and  $D_2$  , one output capacitor  $C_o$  , and one output resistor  $R_L$  .The input and output voltage is signified by  $V_i$  and  $V_o$  respectively. The voltage across  $C_{b1}$  ,  $C_{b2}$ ,  $C_e$  ,  $D_1$  and  $D_2$  are shown by  $V_{cb1}$  ,  $V_{c21}$  ,  $V_{ce}$  ,  $V_{D1}$  , and  $V_{D2}$  , respectively. The currents flowing through  $L_1$ ,  $L_2$  and  $D_o$  are denoted by  $i_{L1}$  ,  $i_{L2}$  and  $i_{D0}$  respectively.

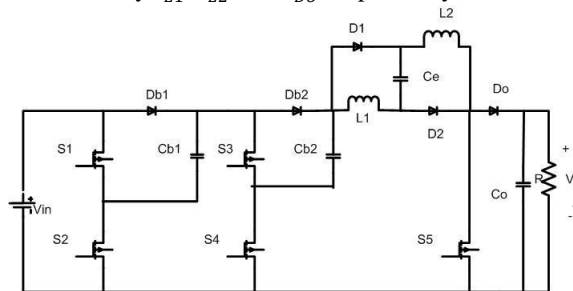


Figure 2: High Voltage Boost Converter Based On Boot Strap capacitor and boost inductor

### A. BASIC OPERATING PRINCIPLE

The converter operated in the CCM are to be analysed in the following, under the condition that  $L_1$  is equal to  $L_2$ .

Mode 1: The switches  $S_1$ ,  $S_3$  and  $S_5$  are turned on, but  $S_2$ ,  $S_4$  is turned off as shown in figure 3.  $D_o$  is reverse biased , due to  $S_5$  being turned on but  $D_1$  and  $D_2$  are forward biased, thereby causing  $C_e$  to be abruptly charged to  $V_i$  plus  $2 V_{cb}$  . Due to  $S_1$  , being turned on,  $D_{b1}$ , is reverse biased, thereby causing  $C_{b1}$  , to be discharged.  $D_{b2}$  , is reverse biased due to  $S_3$  , being turned on, thereby causing  $C_{b2}$  , to be discharged. The voltages across  $L_1$ , and  $L_2$  are  $V_i$  plus  $V_{cb}$  , thereby causing  $L_1$ , and  $L_2$  to be magnetized and  $C_o$  releases energy to the output.

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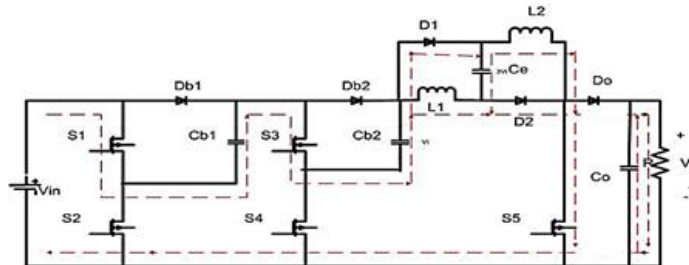


Figure 3. Proposed converter operating in model 1.

The voltages across,  $L_1$ , and  $L_2$   $V_{L1-on}$  and  $V_{L2-on}$ , can be written as

$$V_{L1-on} = V_i + V_{cb1} + V_{cb2} \quad (1)$$

$$V_{L2-on} = V_i + V_{cb1} + V_{cb2} \quad (2)$$

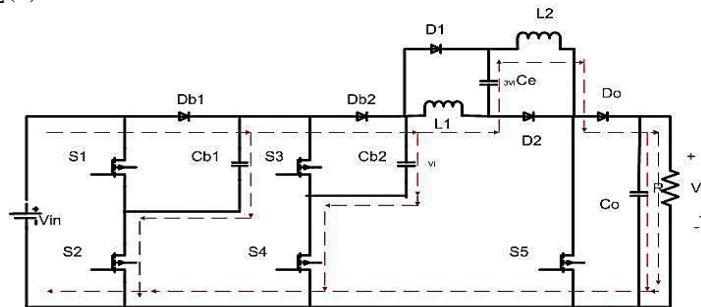


Figure 4. Proposed converter operating in mode 2.

Mode 2: As shown in Fig 4. the switches  $S_1$ ,  $S_3$  and  $S_5$  are turned off, but  $S_2, S_4$  is turned on.  $D_{b1}$  is forward biased thereby causing  $C_{b1}$ , to be abruptly charged to  $V_i$ . Due to  $S_4$ , being turned on,  $D_{b2}$ , is forward biased, thereby causing  $C_{b2}$  to

be abruptly charged to  $V_i$ . The input voltage plus the energy stored in  $C_e$ , plus the energy stored in  $L_1$ , and  $L_2$  supplies the load. The output voltage is boosted up, and is much higher than the input voltage. The voltages and  $V_{L1-off}$ ,  $V_{L2-off}$ , and  $V_o$  in this mode can be expressed as

$$V_{L1-off} = \frac{-D}{1-D} \times V_{L1-on} \quad (3)$$

$$V_{L2-off} = \frac{-D}{1-D} \times V_{L2-on} \quad (4)$$

$$V_o = -V_{L1-off} - V_{L2-off} + V_i + V_{ce} \quad (5)$$

Since  $V_{cb}$  and  $V_{ce}$  are equal to  $V_i$  and  $3V_i$  respectively, (1), (2) and (5) can be written as

$$V_{L1-on} = V_{L2-on} = 3V_i \quad (6)$$

$$V_o = -V_{L1-off} - V_{L2-off} + 4V_i \quad (7)$$

By substituting (3) into (6) and (7)

$$V_{L1-off} = V_{L2-off} = \frac{-D}{1-D} \times 3V_i \quad (8)$$

Substituting (8) into (7) yields the following CCM voltage conversion ratio conversion Ratio

$$V_o = -\left(\frac{-D}{1-D} \times 3V_i\right) - \left(\frac{-D}{1-D} \times 3V_i\right) + 4V_i$$

$$\frac{V_o}{V_i} = \frac{4+2D}{1-D}$$



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## III. SIMULATION RESULT AND DISCUSSION

The high voltage boost converter and boost converter were simulated in MAT-LAB/Simulink. The converter is fed from a 48 V DC supply and the output of the converter is seen to be 380V DC. The power output of the converter is 360W. Simulation diagram and results were shown in following section.

The specifications of the boost converters are given as follows: 1) The rated dc input voltage  $V_i$  is set to 48 V DC. 2) The rated dc output voltage  $V_o$  is set to 360 V DC. 3) The rated output power is set to 360 W. 4) Switching frequency  $f_s$  is 40kHz.

Simulation parameters for the boost converter can be obtained from the following equations.

- Design of bootstrap capacitor,  $C_b$

$$C_b = \frac{2 P_o \times D}{f_s \times (V_i)^2}$$

- Design of Inductor  $L_1$  and  $L_2$

$$L_1 = L_2 = \frac{V_i \times D}{f_s \times \Delta I_L \times P}$$

- Design of output capacitor  $C_o$

- $$C_o = \frac{I_o \times D}{f_s \times \Delta V_o}$$

$\Delta V_o$  is the ripple voltage

Table below shows the circuit parameters used in High voltage boost converters.

Capacitor $C_b$	100 $\mu$ F
Capacitor $C_e$	220 $\mu$ F
Output capacitor $C_o$	680 $\mu$ F
Output voltage $V_o$	380V
Switching frequency $f_s$	40kHz
Input voltage $V_i$	48V
Inductor $L_1$ and $L_2$	170 $\mu$ H
Load resistor $R_L$	400
Duty ratio D	0.3

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## A. OPEN LOOP CONTROL OF HIGH VOLTAGE BOOST CONVERTER

The high voltage boost converter with duty ratio 0.3 is simulated with the simulation diagram shown in Fig.5. The input to the converter is fed from 48 V DC supply. The output obtained is 360 V DC at duty ratio 0.3. PWM signal is used to give gate pulses to the switches in the converter.

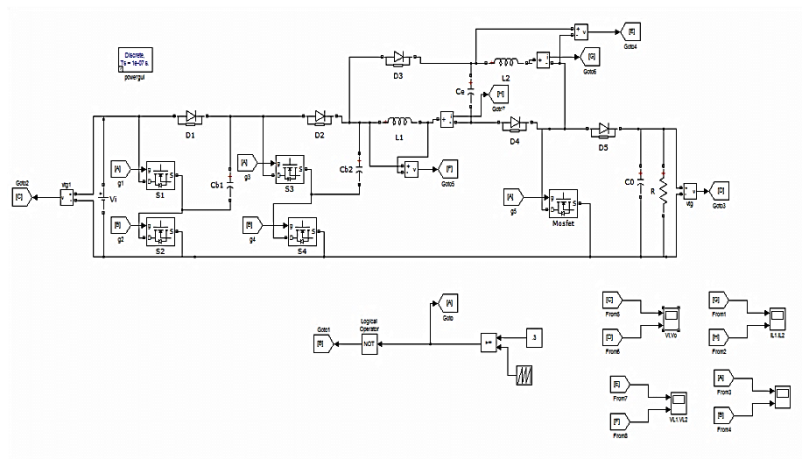


Figure 5: Simulation diagram of high voltage boost converter.

The waveform of gate pulses to the switches  $S_1$ ,  $S_3$  and  $S_5$  were shown in figure 6 and gate pulses for switches  $S_2$  and  $S_4$  were shown in figure 7.

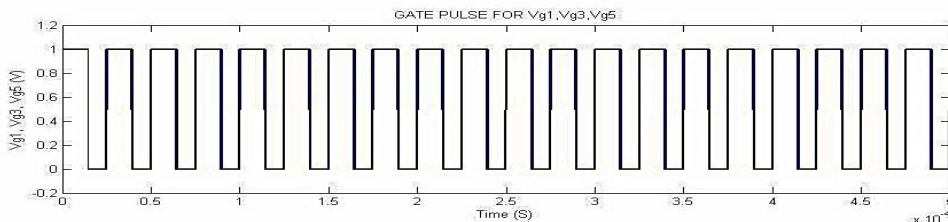


Figure 6: Gate pulses for switch  $S_1$ ,  $S_3$  and  $S_5$ .

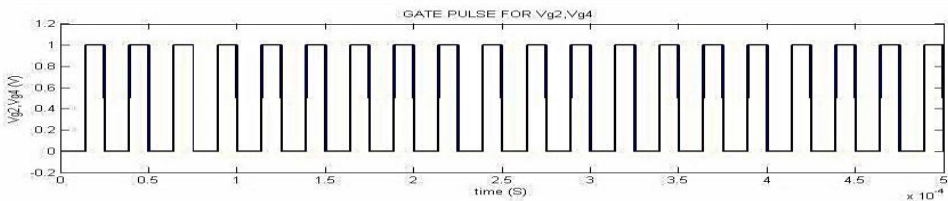


Figure 7: Gate pulses for switch  $S_2$  and  $S_4$ .

The input voltage and output voltage waveform of boost converter were shown in figure below.

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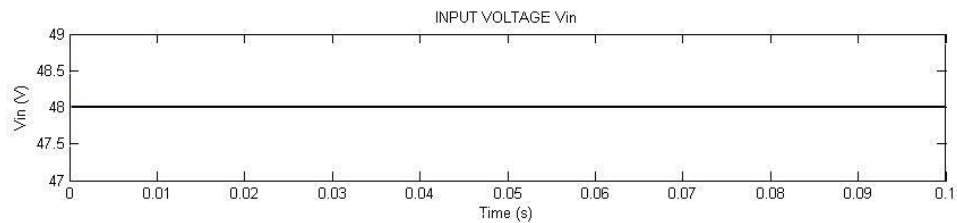


Figure 8: Input Voltage waveform of high voltage boost converter

The input voltage to the boost converter is 48V DC and the output voltage obtained is 360V.

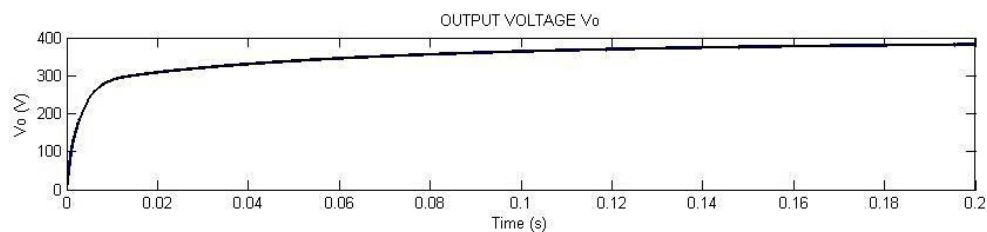


Figure 9: Output Voltage waveform of high voltage boost converter .

In figure 5.10 and 5.11, the inductor currents  $i_{L1}$  and  $i_{L2}$  are shown.

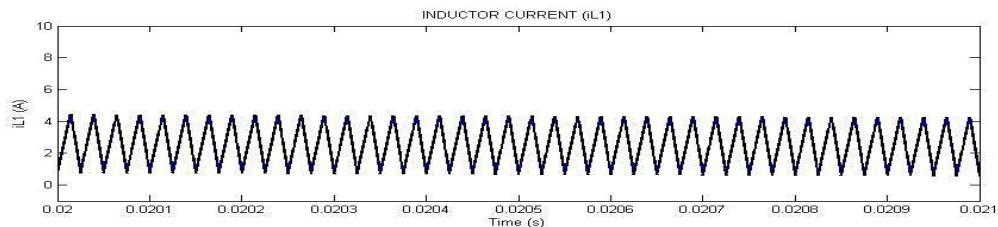


Figure 5.10: Inductor current waveform  $i_{L1}$  of boost converter.

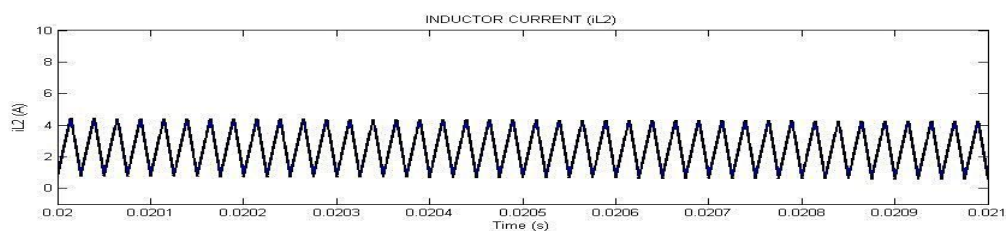


Figure 5.11: Inductor current waveform  $i_{L2}$  of boost converter

## B. SIMULATION OF CLOSED LOOP CONTROL OF BOOST CONVERTER

The simulation diagram of closed loop control of modified high voltage boost converter is shown in figure 6.12. To maintain the output voltage constant irrespective of changes in load and input voltage , a PI Controller is used. By using a PI controller output voltage is maintained at 360 V DC.

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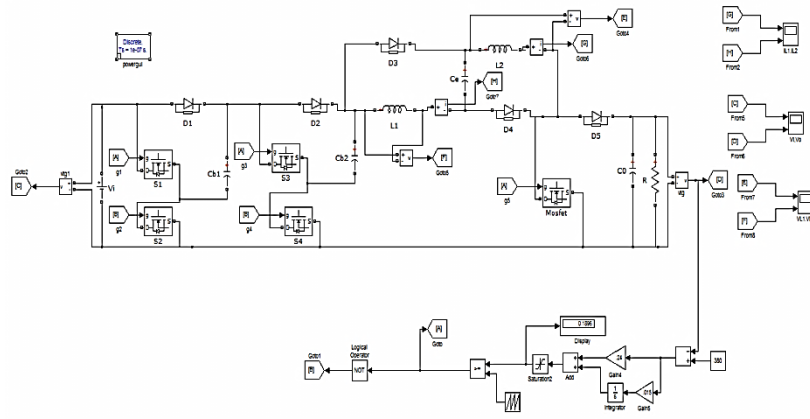


Figure 6.12: Circuit diagram of closed loop control of high voltage boost converter

The input voltage and output voltage waveform of the closed loop control of boost converter were shown in figure below.

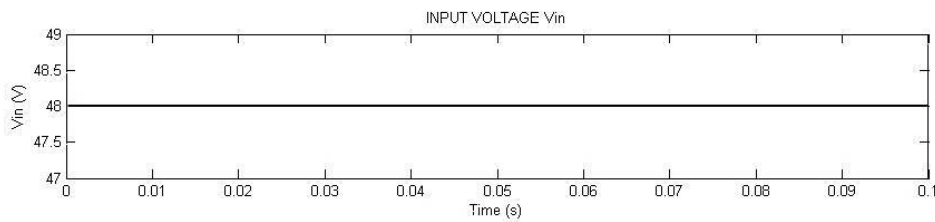


Figure 6.14 Input Voltage waveform of boost converter

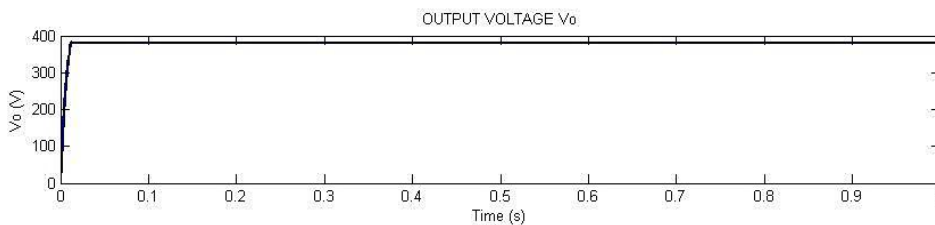


Figure 6.15: Output Voltage waveform of boost converter.

By using close loop controller output is maintained constant even though the input voltage changes. The transient responses also improved. The settling time also improved.

In figure 5.16 and 5.17, the inductor currents  $i_{L1}$  and  $i_{L2}$  are shown.

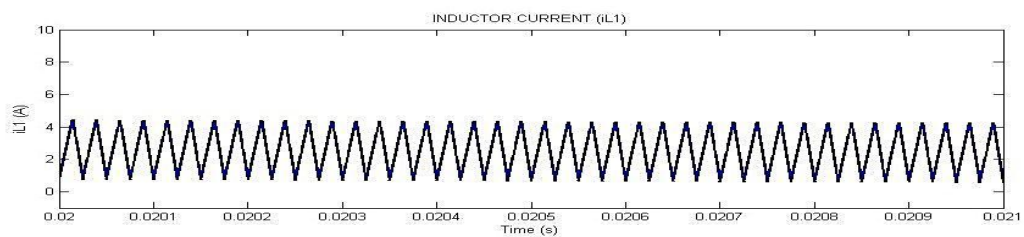


Figure 6.15: Inductor current waveform  $i_{L1}$  of boost converter.

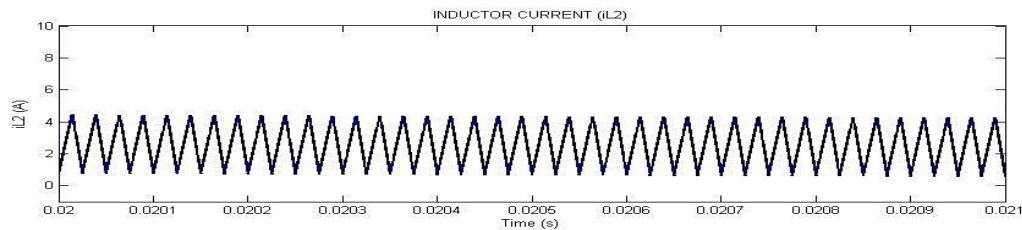


Figure 6.16: Inductor current waveform  $i_{L2}$  of boost converter.

#### IV. CONCLUSION

In this paper, high voltage-boosting converters are proposed. The proposed converter is based on inductors connected in series with bootstrap capacitors. The converter has high voltage conversion ratio than conventional boost converter. The conversion ratio is  $(4+2D)/(1-D)$ . Open loop and closed loop control of boost converter is simulated using MATLAB/SIMULIK. Closed loop control is done using PI controller in order to maintain output voltage constant at 380 V DC which is the standard DC bus voltage for telecommunication industry.

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