Comparative Analysis of Boost and Cascaded Boost Converter

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Abstract: - In this paper, an overall comparison between the Boost Converter (BC) & Cascaded Converter or Cascaded Boost Converter (CBC) is given in terms of ideal condition, as well as with the consideration of Equivalent Series Resistance (ESR) of inductor. The loss comparison in the two converters due to the ESR is also included in this paper. It is seen that in CBC, voltage gain is more but the power loss due to ESR is also more compared to the BC. The parameters of the converters are found out with a consideration of per unit ripple quantity of inductor current and capacitor voltage. A boundary condition between the continuous conduction mode (CCM) & discontinuous conduction mode (DCM) of the inductor current is also shown. The behaviour of the capacitor current for the converters is discussed during ON and OFF condition of the switch(es). At the end, the simulation results of both the converters are given for a 20V/100V, 100 W output. The analysis and simulation results are presented in this paper for the verification of the feasibility.

Key-Words: - boundary condition**,** capacitor current, cascaded converter, DC-DC converter, inductive ESR, ESR loss comparison, simulation

1 Introduction

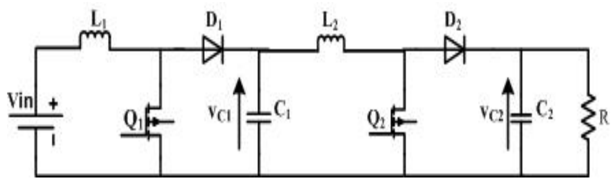
DC - DC conversion is becoming very important in various portable applications now a days. Many portable devices use power at different levels of voltage. The modern technology is making the renewable energy sources (RES) to become an alternative of the combustion engines for power generation as the cost and the environmental issues are concerned.[1-6]But the main hindrance behind RES is less voltage generation per cell.[7] So to fulfill the requirement of high voltage applications, a number of cells to be connected is series or parallel combination. It further reduces the energy generation due to shadow effect on the PV cells.[8-11] So a voltage step up process can be used with a fuel cell (FC) or Photovoltaic (PV) cell to boost the output voltage and thus the efficiency can also be increased.[12-13] As the dc-dc converter injects less current ripple into the source, the efficiency as well as the life span can be increased with that for the PV or FC array. [14-15]

The voltage build up can be possible by BC and CBC. [16-17]BC can not give the significant build up of output voltage for the same duty ratio as compared to CBC as the output voltage of the later one is a quadratic function of duty cycle. Again for BC as high voltage generation requires a large duty cycle, so it further inceases the reverse recovery effect of the diodes.[18-19]

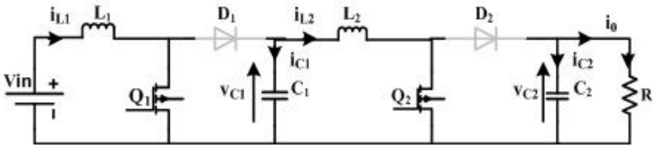
The comparative study of the two converters is focussed in this paper along with the consideration of ESR of the inductor(s) in section 3 and power losses due to the ESR effect is discussed in section 4. In section 5, converter parameters are designed with a discussion about the stresses on the switch(es). Section 6 depicts about the boundary condition between continuous conduction mode (CCM) & discontinuous conduction mode (DCM) of inductor current. Behaviour of the capacitor current and the simulation performances are shown in section 7 & 8 respectively.

2 Operation of the Converters

2.1 Cascaded Boost Converter:



(a)



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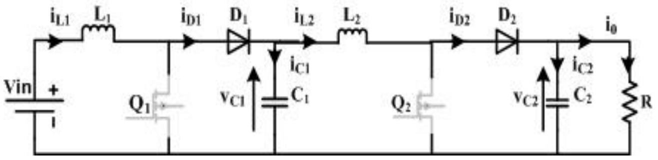


(c)

Fig. 1(a),(b),(c) Cascaded Boost Converter, Switches are in ON state, Switches are in OFF state

The CBC is shown in Fig. 1(a) where v_{in} is the input voltage, Q_1, Q_2 – are two active switches, D_1, D_2 are the passive switches and L_1, L_2 & C_1, C_2 are the corresponding values of Inductance and Capacitor of the converter. The output voltage is represented by $v_0 = v_{C2}$. The duty ratio is termed as *k* here.

The steady state parameters of the converter can be found out by considering the ON and OFF conduction mode of the switches, Q_1 & Q_2.

The ON state of the switches is shown in Fig. 1(b). In this condition inductor current i_{L1} is flowing through the switch Q_1 and i_{L2} through Q_2. So switch current $i_{Q1} = i_{L1}$ and $i_{Q2} = i_{L2}$. The diodes, D_1 & D_2 are reverse biased as shown by light color. The capacitor C_1 discharges through the inductor L_2 - Q_2, as well as C_2 discharges through the load resistance R. The load current is shown as i_0.

During the OFF mode of the switches, no current is flowing through the switch Q_1 and Q_2 as shown in Fig. 1(c). The diodes D_1, D_2 becomes forward biased now. Current passing through the diodes are i_{L1} & i_{L2} respectively. The output voltage across the load is same as the capacitor voltage, v_{C2}.

To find the steady state parameters I_{L1}, I_{L2} and V_{C1}, V_{C2} the following method has been followed:

During ON & OFF time of the switches,

Average voltage drop across inductor L_1,

$$V_{L1}^{ON}=kV_{in},\quad V_{L1}^{OFF}=(1-k)(V_{in}-V_{C1})$$

Average voltage drop across inductor L_2,

$$V_{L2}^{ON}=kV_{C1},\quad V_{L2}^{OFF}=(1-k)(V_{C1}-V_{C2})$$

Average current passing through capacitor C_1,

$$I_{C1}^{ON}=-kI_{L2},\quad I_{C1}^{OFF}=(1-k)(I_{L1}-I_{L2})$$

Average current through the capacitor C_2,

$$I_{C2}^{ON}=-kI_0,\quad I_{C2}^{OFF}=(1-k)(I_{L2}-I_0)$$

The average voltage drop across any inductor is zero,

i.e., $V_L^{ON}+V_L^{OFF}=0$.

Solution of this above expression gives as,

$$V_{C1}=\frac{V_{in}}{(1-K)} \tag{1}$$

$$V_{C2}=\frac{V_{in}}{(1-k)^2} \tag{2}$$

Average current passing through any capacitor is zero, i.e., $I_C^{ON}+I_C^{OFF}=0$.

From the solution of the above expression,

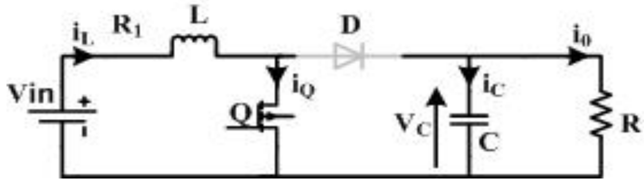
$$I_{L1}=\frac{V_{in}}{(1-k)^4R} \tag{3}$$

$$I_{L2}=\frac{V_{in}}{(1-k)^3R} \tag{4}$$

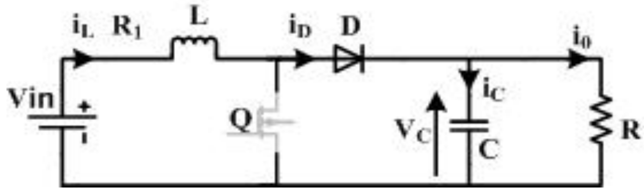
Output voltage of CBC,

$$V_0=V_{C2}=\frac{V_{in}}{(1-k)^2}$$

2.2 Boost Converter:



(a)



(b)

Fig. 2(a) Boost converter in ON mode, Fig. 2(b) Boost converter in OFF mode

The BC is shown in Fig. 2(a), (b) where V_{in} is the input voltage, Q – an active switch, D is the passive switch and L & C are the corresponding values of Inductance and Capacitor of the converter. The output voltage is represented by v_0=v_c. The duty ratio is termed as *d* here.

The On state of the boost converter is shown in Fig. 2(a) and OFF state in Fig. 2(b). The BC is also operating in the same way as the CBC. The inductor current is flowing through the switch Q during ON time and through the diode during OFF time of the switch.

The output voltage equals the capacitor voltage as shown in the Fig. 2(a) and 2(b).

Steady state parameters of the converter can be found out by following the method stated above.

$$V_C = \frac{V_{in}}{(1-d)} \tag{5}$$

$$I_L = \frac{V_{in}}{(1-d)^2 R} \tag{6}$$

Output voltage of the BC,

$$V_0 = V_C = \frac{V_{in}}{(1-d)}$$

The relation between the duty ratios of the two converters with a same voltage gain can be given as-

$$d = 1 - (1-k)^2 \tag{7}$$

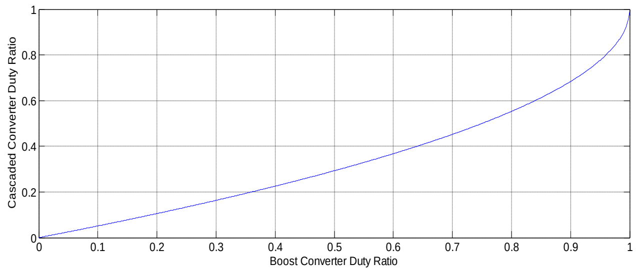


Fig. 3 Comparison between the Boost converter and cascaded boost converter duty ratio at the same voltage gain

It is seen from the curve of Fig. 3 that for the same voltage gain, less duty ratio is required in CBC compared to BC. So a CBC can provide more voltage build up compared to BC with a less duty ratio.

3 Effect of inductive ESR

In section 2, the discussion is related to the ideal converters. But practically in all converters, the inductance is under the influence of a series connected resistor or ESR. Due to the presence of such ESR, the converter performance or the efficiency cannot be practically same as that of the ideal converters. In this section the ESR effect of the two converters is discussed with the loss calculation due to the said ESR effect in the next section.

3.1 Cascaded Boost Converter:

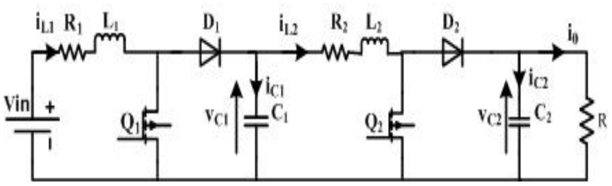


Fig. 4 Inductive ESR in cascaded boost converter

To find the steady state parameters of the CBC due to the ESR effect of the inductor, the following method is applied:

During ON & OFF time of the switches,
Average voltage drop across the inductor L_1,

$$V_{L1}^{ON} = k(V_{in} - I_{L1}R_1) \tag{8}$$

$$V_{L1}^{OFF} = (1-k)(V_{in} - I_{L1}R_1 - V_{C1}) \tag{9}$$

Average voltage drop across inductor L_2,

$$V_{L2}^{ON} = k(V_{C1} - I_{L2}R_2) \tag{10}$$

$$V_{L2}^{OFF} = (1-k)(V_{C1} - V_{C2} - I_{L2}R_2) \tag{11}$$

Average current passing through capacitor C_1,

$$I_{C1}^{ON} = -kI_{L2} \tag{12}$$

$$I_{C1}^{OFF} = (1-k)(I_{L1} - I_{L2}) \tag{13}$$

Average current through the capacitor C_2,

$$I_{C2}^{ON} = -kI_0 \tag{14}$$

$$I_{C2}^{OFF} = (1-k)(I_{L2} - I_0) \tag{15}$$

Average voltage drop across any inductor is zero and the average current passing through the capacitor is also zero. So,

$$V_L^{ON} + V_L^{OFF} = 0 \tag{16}$$

$$I_C^{ON} + I_C^{OFF} = 0 \tag{17}$$

Solution of the equations (16) & (17) with reference to equations (8) – (15), the steady state parameters of the cascaded converter due to ESR effect can be obtained as-

$$I_{L1} = \frac{V_{in}}{(1-k)R_1 + (1-k)^4 R + (1-k)^2 R_2} \tag{18}$$

$$I_{L2} = \frac{V_{in}}{R_1 + (1-k)^3 R + (1-k)R_2} \tag{19}$$

$$V_{C1} = \left\{\frac{(1-k) + \frac{R_2}{(1-k)R}}{\frac{R_1}{(1-k)^2 R} + (1-k)^2 + (1-k)R_2}\right\} V_{in} \tag{20}$$

$$V_{C2} = \frac{V_{in}}{R_1 + (1-k)^3 R + (1-k)R_2} \tag{21}$$

3.2 Boost Converter:

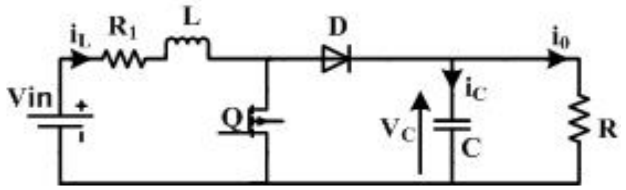


Fig.5 Inductive ESR in Boost converter

The steady state parameters of the BC can be found as,

$$I_L = \frac{V_{in}}{\left\{(1-d) + \frac{R_1}{(1-d)R}\right\}(1-d)R} \tag{22}$$

$$V_C = \frac{V_{in}}{(1-d) + \frac{R_1}{(1-d)R}} \tag{23}$$

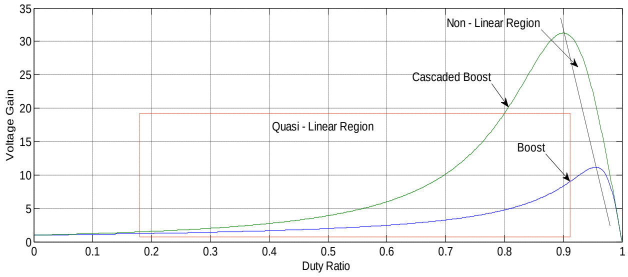


Fig. 6 Shows the Voltage gain ratio with ESR (0.1 Ω) for the two converters

Fig. 6 shows the comparative analysis of the CBC and the BC voltage gain when equal ESR of all the inductor is considered. It is clearly understood from the curve that the attainable voltage gain in CBC is even more as compared to BC even if with the losses of due to the ESR effect.

Both the converters can work within the Quasi – Linear region only. Beyond that the Non – Linear region appears, where the performance of the converters is disturbed & they cannot be operated. The duty cycle for the operating point of the cascaded converter is less with comparison to BC operating point duty cycle.

4 Losses Due to Inductive ESR

Theoretically DC-DC converters can provide a infinite voltage gain. But practically it is never possible as there are some inherent parasitic elements present such that ESR. In this section the losses due to ESR effect of the inductor is considered. The losses have more impact when the device is used for any low power application. [20-21]So the loss calculation is discussed as under:

The value of the inductor,

$$L \propto \frac{N^2 A}{l} \tag{24}$$

where, N = no. of turns in the inductor,
A = cross sectional area of the inductor
L = length of the inductor
Again the length, $l \propto N$
So equation (24) can be written as,

$$L \propto NA \tag{25}$$

Since the current passing through the conductor,

$$I_L \propto x^{3/2}$$

Cross sectional area,

$$A \propto x^2 \propto I_L^{4/3} \tag{26}$$

where, x is the diameter of the conductor.
The equation (25) now can be re-arranged as,

$$L \propto N I_L^{4/3} \tag{27}$$

The ESR value,

$$R \propto \frac{l}{A} \propto \frac{N}{I_L^{4/3}} \tag{28}$$

So the ESR per unit Inductor is,

$$\frac{R}{L} \propto \frac{1}{I_L^{8/3}} \tag{29}$$

For BC, ESR of the inductor L,

$$R_{esr} \propto \frac{L}{I_L^{8/3}} \tag{30}$$

For CBC,
ESR of the inductor L_1,

$$R_{esr1} \propto \frac{L_1}{I_{L1}^{8/3}} \tag{31}$$

ESR of the inductor L_2,

$$R_{esr2} \propto \frac{L_2}{I_{L2}^{8/3}} \tag{32}$$

Since, in the cascaded converter, $I_{L2} = (1-k)I_{L1}$, equation (32) can be written as,

$$R_{esr2} \propto \frac{L_2}{\{I_{L1}(1-k)\}^{8/3}} \tag{33}$$

Since the input power for the Boost as well as Cascaded converter is same. So for the same input voltage, $I_L = I_{L1}$.

Thus the relation between the ESR values of L_1 inductor in CBC to the ESR value of BC inductor L can be given as,

$$R_{esr1} = \frac{L_1}{L} R_{esr} \tag{34}$$

In the same way,

$$R_{esr2} = \frac{L_2}{L(1-k)^{8/3}} R_{esr} \tag{35}$$

Power losses in the BC,

$$P_B = I_L^2 R_{esr} \tag{36}$$

Power loss in the inductors of CBC,

$$P_{L1} = I_{L1}^2 R_{esr1}$$

$$P_{L2} = I_{L2}^2 R_{esr2}$$

Total loss in the CBC due to inductive ESR,

$$P_C = P_{L1} + P_{L2}$$

$$= I_{L1}^2 \{R_{esr1} + (1-k)^2 R_{esr2}\} \tag{37}$$

So the power loss ratio of the CBC to the BC can be derived as,

$$\frac{P_C}{P_B} = \frac{k}{\{1-(1-k)^2\}} \left\{1 + \frac{1}{(1-k)^{5/3}}\right\} \tag{38}$$

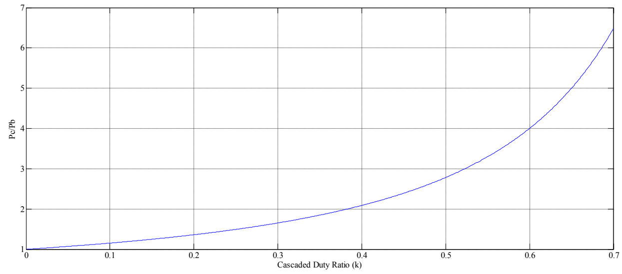


Fig.7 shows power loss ratio curve due to inductive ESR

Fig. 7 shows the power loss ratio curve in CBC to BC with a change in the duty ratio of the CBC. It is seen that with an increment of the duty ratio, the voltage gain of the CBC increases. But the power loss due to the inductive ESR effect also increases compared to the conventional BC.

The on state loss of the Cascaded converter is less compared to the BC for the same voltage gain. Whereas the off state loss is more in BC compared to CBC.

5 Parameter Design

The designing of the parameters of the CBC is considered here in terms of per unit ripple in the inductor current $(\Delta I_L/I_L)$ and per unit ripple in the capacitor voltage $(\Delta V_C/V_C)$.

During ON time of the switches, voltage drop across the inductor L_1,

$$L_1 \frac{di_{L1}}{dt} = V_{in} \tag{39}$$

Considering the ripple current in the inductor as ΔI_{L1}, equation (39) gives the solution as,

$$L_1 = \frac{kT_s V_{in}}{\Delta I_{L1}} \tag{40}$$

The inductor value can be found in terms of per unit ripple from equation (40) as,

$$L_1 = \frac{kT_s V_{in}}{per\ unit\ ripple\ \ x\ I_{L1}} \tag{41}$$

Equation (3) can be placed in equation (41) and thus,

$$L_1 = \frac{k(1-k)^4 RT_s}{per\ unit\ ripple} \tag{42}$$

where, T_s is the switching frequency = $1/f_s$

Second inductor L_2 value can also be found out in the same way as,

$$L_2 = \frac{k(1-k)^3 RT_s}{per\ unit\ ripple} \tag{43}$$

Current passing through the capacitor C_1 during the ON time of the switches,

$$i_{C1} = C_1 \frac{dv_{C1}}{dt} = i_{L2}$$

$$C_1 \frac{\Delta v_{C1}}{k\ T_s} = \frac{V_{in}}{(1-k)^3 R} \tag{44}$$

The capacitor values can be found out by considering a per unit ripple in the capacitor voltage in the same way as,

$$C_1 = \frac{kT_s}{(1-k)^2 R\ x\ per\ unit\ ripple} \tag{45}$$

$$C_2 = \frac{kT_s}{R\ \ x\ per\ unit\ ripple} \tag{46}$$

A CBC as shown in Fig. 1(a) where the nominal values considered as: input voltage V_{in} = 20 V, output voltage V_0 = 100 V, the nominal duty ratio k = 0.55. Considering a 2% ripple in the inductor current and the capacitor voltage as well with switching frequency f_s = 20 kHz. To make a 100 W converter, the parameters can be found out by the equations (42), (43), (45) & (46) is shown in Table 2.

During BC designing the value of the inductor and the capacitor can also be found out by the same way as shown above.

$$L = \frac{d(1-d)^2 RT_s}{per\ unit\ ripple} \tag{47}$$

$$C = \frac{dT_s}{R\ \ x\ per\ unit\ ripple} \tag{48}$$

When the switches are ON, the current passing through them is the current stress on the switches whereas during OFF condition of the switches the voltage stress can be obtained. The current stress will be the maximum peak current passing through the respective switch. But since the voltage ripple is considered as very small, so the voltage stress will be as same as the average value of the voltage applied to the switch.

In CBC, the current stress on the switches is as follows:

$i_{Q1peak} = i_{L1peak}$; $i_{Q2peak} = i_{L2peak}$

$i_{D1peak} = i_{L1peak}$; $i_{D2peak} = i_{L2peak}$

Table 1
Parameter comparison of Boost & Cascaded Boost Converter

Parameters	BC	CBC
Voltage Gain	$\frac{1}{(1-d)}$	$\frac{1}{(1-k)^2}$
Inductor value(s)	$\frac{d(1-d)^2RT_s}{per\ unit\ ripple}$	$L_1 = \frac{k(1-k)^4RT_s}{per\ unit\ ripple}$
		$L_2 = \frac{k(1-k)^3RT_s}{per\ unit\ ripple}$
Capacitor value	$\frac{dT_s}{R\ x\ per\ unit\ ripple}$	$C_1 = \frac{kT_s}{(1-k)^2R\ x\ per\ unit\ ripple}$
		$C_2 = \frac{kT_s}{R\ x\ per\ unit\ ripple}$
Voltage stress on switch	$\frac{V_{in}}{(1-d)}$	$V_{Q1}\frac{V_{in}}{(1-k)}$
		$V_{Q2} = \frac{V_{in}}{(1-k)^2}$
Inductor Current	$I_L = \frac{V_{in}}{(1-d)^2R}$	$I_{L1} = \frac{V_{in}}{(1-k)^4R}$
		$I_{L2} = \frac{V_{in}}{(1-k)^3R}$
Current stress on switch	$i_{Qpeak} = I_L + \frac{d}{2Lf_s}V_{in}$	$i_{Q1peak} = I_{L1} + \frac{k}{2L_1f_s}V_{in}$
		$i_{Q2peak} = I_{L2} + \frac{k}{2L_2f_s}V_{in}$
Current stress on Diode	$i_{Dpeak} = I_L + \frac{d}{2Lf_s}V_{in}$	$i_{D1peak} = I_{L1} + \frac{k}{2L_1f_s}V_{in}$
		$i_{D2peak} = I_{L2} + \frac{k}{2L_2f_s}V_{in}$

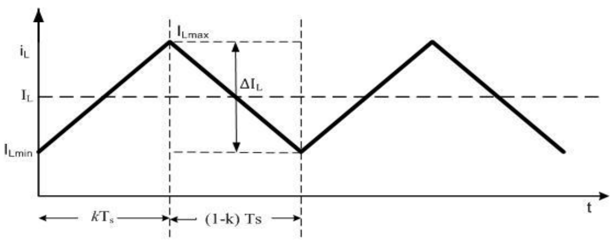


Fig. 8 shows inductor current ripple with minimum and maximum peak

In Fig. 8 the inductor current with the maximum and the minimum value of the ripple is shown. The peak value of the inductor can be found out as:

$$I_{Lmax} = I_L + \Delta I_L/2 \quad (49)$$

Taking the reference of equation (40), the current stress equation of the inductor can be written as,

$$I_{Lmax} = I_L + \frac{duty\ ratio}{2Lf_s}V_{in} \quad (50)$$

Table 2
Parameter comparison of Boost & Cascaded Boost Converter for 100W

Parameters	Boost Converter	Cascaded Boost
Duty Ratio	0.80	0.55
Inductor value	L = 4 mH	L_1 = 2.82 mH L_2 = 6.26 mH
Capacitor value	C = 40 µF	C_1 = 136 µF C_2 = 27.5 µF
Load Resistance R	50 Ω	50 Ω
Voltage stress on switch	V_Q = 100 V	$V_{Q1} = 50\ V$ $V_{Q2} = 100\ V$
Current stress on switch	i_{Qpeak} = 10.1 A	$i_{Q1\ peak}$= 9.85 A $i_{Q2\ peak}$= 4.43 A
Current stress on Diode	i_{Dpeak} = 10.1 A	i_{D1peak}= 9.85 A i_{D2peak}= 4.43 A

So the current stress on the switch Q_1 & D_1,

$$i_{Q1peak} = i_{D1peak} = I_{L1} + \frac{k}{2L_1f_s}V_{in} \quad (51)$$

Current stress on the switch Q_2 and D_2,

$$i_{Q2peak} = i_{D2peak} = I_{L2} + \frac{k}{2L_2f_s}V_{in} \quad (52)$$

In case of the BC, the current stress on the switch and the diode will be as,

$$i_{Qpeak} = i_{Dpeak} = I_L + \frac{d}{2Lf_s}V_{in} \quad (53)$$

6 Boundary Between CCM & DCM

The boundary between the CCM & DCM can be derived only when the inductor current touches zero. During the OFF state of the switches, the inductor current gradually reduces to a minimum value I_{Lmin} as shown in Fig.8.

The value of the lowest inductor current can be found as,

$$I_{Lmin} = I_L - {}^{\Delta I_L}/_2 \quad (54)$$

Equation (54) can be re-written with reference to equation (50) as,

$$I_{Lmin} = I_L - \frac{duty\ ratio}{2Lf_s} V_{in} \quad (55)$$

For the BC, equation (55) can be written as,

$$I_{Lmin} = I_L\{1 - \frac{d(1-d)^2 R}{2Lf_s}\} \quad (56)$$

As the condition for the boundary condition to be satisfied,

$$I_{Lmin} = I_L\{1 - \frac{d(1-d)^2 R}{2Lf_s}\} = 0 \quad (57)$$

The solution of the above equation gives the value of inductor for the boundary condition as,

$$L = \frac{d(1-d)^2 R}{2f_s} \quad (58)$$

In the same way the value of the inductors for the boundary condition can be found out for the CBC as,

$$L_1 = \frac{k(1-k)^4 R}{2f_s} \quad (59)$$

$$L_2 = \frac{k(1-k)^3 R}{2f_s} \quad (60)$$

7 Behavior of the Capacitor Current

The capacitor of the BC as shown in Fig. 2(a) has to discharge through the load resistance during ON state of the switch and to be charged during the OFF state of the switch as shown in Fig. 2(b). But practically the charging and discharging does not always depend upon the switching period. It may depend upon the value of minimum inductor current and the output current.

When $I_{Lmin} > I_0$ as shown in Fig. 8, the capacitor charges during ON time and discharges during the OFF time of the switch. But when $I_{Lmin} < I_0$, the capacitor does not wholly operate in the same way as stated above. During ON time, capacitor discharges through the load; but during OFF time, the capacitor is getting charged until $I_{Lmin} < I_0$. As soon as the inductor current falls below the output current level, capacitor starts to discharge to maintain a constant average load current. So in DCM, capacitor charging-discharging does not depend upon the switching time periods.

7.1 Condition for $I_{Lmin} > I_0$ & $I_{Lmin} < I_0$:

The OFF state average inductor current in BC is equal to the average output current since the average capacitor current is zero. So the condition can be written with reference to Fig. 8 as,

$$I_0 = \frac{{}^1/_2(1-d)T_s\Delta I_L + I_{Lmin}\,(1-d)T_s}{T_s} \quad (61)$$

$$\text{So, } I_{Lmin} = I_0\left[\frac{1}{(1-d)} - \frac{\Delta I_L(1-d)R}{2V_{in}}\right] \quad (62)$$

Equation (62) clearly states that,

when, $\left[\frac{1}{(1-d)} - \frac{\Delta I_L(1-d)R}{2V_{in}}\right] > 1;\ I_{Lmin} > I_0$ and

$\left[\frac{1}{(1-d)} - \frac{\Delta I_L(1-d)R}{2V_{in}}\right] < 1;\ I_{Lmin} < I_0$

The load side capacitor of the CBC is also showing the same behaviour. The relevant waveforms are shown in the Simulation Section.

8 Simulated Performance

Simulation results of the two converters are shown below. The conerters were simulated in MATLAB/ Simulink software.

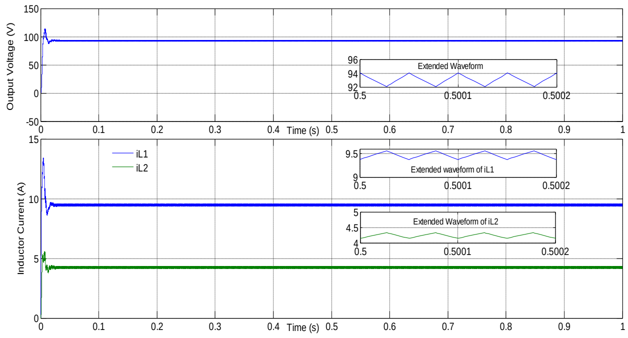


Fig.9 Output voltage waveform (with extended format), i_{L1} & i_{L2} waveform (with extended format) of CBC

The simulation results of CBC are shown in Fig. 9. The output voltage of the converter is constant at 94 V. The inductor currents are continuous in nature and the values of i_{L1}, i_{L2} are 9.75 A & 4.39 A respectively. The peak value of i_{L1}, i_{L2} are respectively 9.85 A & 4.43 A. So the current stress on the switch Q_1 as well as diode D_1 is 9.85 A. Current stress on Q_2 & D_2 is 4.43 A. It is clear that the ripple present in the voltage and current is 2% each. The voltage & current is a bit less due to the parasitic losses in the circuit.

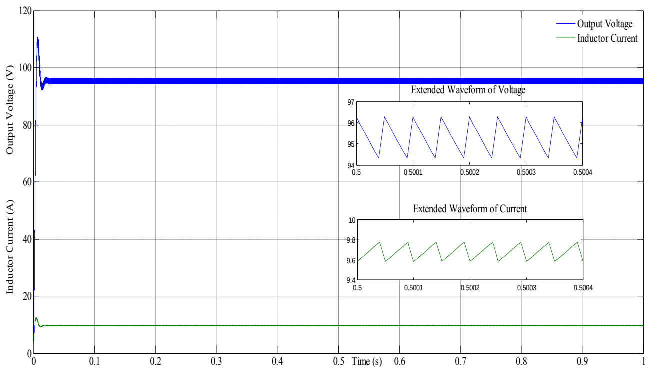


Fig.10 Output voltage & Inductor Current waveforms are shown for BC

Fig. 10 shows the output voltage waveform as a constant at 96 V, inductor current at 10 A. the inductor current is continuous in nature. The peak value of i_L is 9.9 A. So the current stress on the switch Q as well as diode D is 9.9 A. It is clear that the ripple present in the voltage and current is 2% each. Here also some losses present due to parasitic effect.

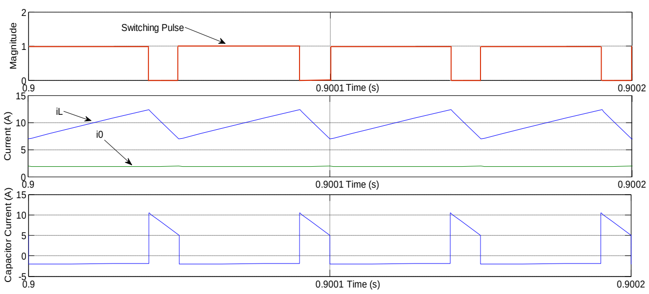


Fig.11 shows the switching pulse, inductor current with output current waveforms & capacitor current waveform for BC when $I_{Lmin} > I_0$

As discussed in section 7, the simulation result of the behaviour of the capacitor current for the BC is shown in fig. 11. Here $I_{Lmin} > I_0$, so the capacitor discharges through the load during ON time of the switch Q, whereas during OFF time of the switch, the capacitor gets charged.

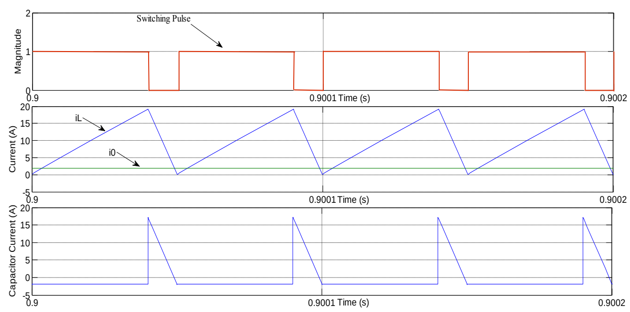


Fig.12 shows the switching pulses, inductor current with output current waveforms & capacitor current waveform for BC when $I_{Lmin} < I_0$

Fig. 12 shows the simulated result of the behaviour of capacitor current when I_{Lmin} falls below I_0. The capacitor discharges during the ON state of the switch as usual. But during OFF state of the switch, capacitor gets charged only when I_{Lmin} more than I_0. At once the capacitor starts to discharge through the load even though the switch in OFF state when I_{Lmin} becomes less than the load current.

The capacitor currents for the CBC also show the same behavior as the BC capacitor current shown above.

9 Conclusion

The main idea behind this paper is to get a clear view of the comparative study of the two converters. The CBC can give a high voltage gain compared with the BC for a given duty ratio. As the switching frequency is fixed, for the same load if the duty ratio is less, the voltage and current ripple is also be less. So the CBC is better option compared to BC. But when ESR losses are considered, the BC is good. That's why for high power application where ESR losses are not a constraint, CBC can be used; whereas for low power application BC is a right choice.

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