OPEN ACCESS

*International*
***Journal***
*Of Modern Engineering Research (IJMER)*

# Analysis of Single Phase Boost Converter and Poly Phase Boost Converters

Boyapati Chandrasekhar[1], Palla Naresh[2]
[1]*PG Scholar, MIT, MANIPAL UNIVERSITY, MANIPAL,*
[2]*PG Scholar, MIT, MANIPAL UNIVERSITY, MANIPAL,*

***ABSTRACT*:-** A boost converter (step-up converter) is a DC to DC power converter, it gives an output of greater than input supply voltage. It is a class of semiconductor, energy storage elements combination. This paper gives an Analysis of single phase boost converter and poly phase boost converters. The poly phase boost converters gives better efficiency and less input ripple compare to single phase boost converter. This comparison done with simulation using MATLAB.

***Keywords*:-** *Single phase boost converter, Poly phase boost Converter, Phase shift, Ripple current*

## I. INTRODUCTION

A boost converter regulates the average output voltage at a level higher than the source voltage. For this reason the boost converter is often referred to as a step-up converter. The DC input voltage is in series with a large inductor acting as a current source. A switch in parallel with the current source and the output is turned on and off periodically, providing energy from the inductor and the source to increase the average output voltage. The boost converter is commonly used in regulated DC power supplies.

The need of poly phase(interleaved) converter is, In designing DC converters, parameters such as ratio of energy stored in inductor and capacitor to energy delivered to load in one period, maximum current in the switch and the value of the RMS current in the output capacitor have great importance and it is necessary to be considered.

One-way of reducing the storage requirement is increasing the switching frequency however this is not practicable in all instances. During the on state of the switch, the capacitor has to supply the entire load current in the boost converter; this discontinuity of current in the capacitor increases the RMS value of current and also increases the amount of capacitor which is needed to keep the ripple voltage low. The power dissipation in the ESR of the capacitor is also high. Overcome this problem is using poly-phase operation with appropriate phase shift in the control circuit of main switches.

## II. SINGLE PHASE BOOST CONVERTER

The general single phase boost topology as shown in fig.1. It has one switch, diode and energy storage elements.

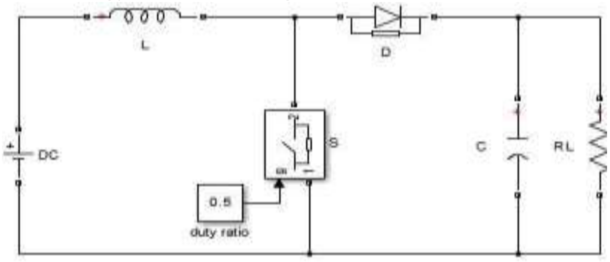



**Fig.1. Single phases boost converter**

During the $dt_s$ period when switch s ON the state space Model is

$$\begin{bmatrix} \dot{i_l} \\ \dot{v_c} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} i_l \\ v_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} \\ 0 \end{bmatrix} [v_g] + \begin{bmatrix} 0 \\ -\frac{1}{C} \end{bmatrix} [i_z]$$

During $(1-d)t_s$ period when the switch s OFF the State space model is

$$\begin{bmatrix}\dot{i_l}\\ \dot{v_c}\end{bmatrix} = \begin{bmatrix}0 & -\frac{1}{L}\\ \frac{1}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}i_l\\ v_c\end{bmatrix} + \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}[v_g] + \begin{bmatrix}0\\ -\frac{1}{C}\end{bmatrix}[i_z]$$

we can represent the load as constant current load and assume that as $i_z$, in $dt_s$ time period the capacitor support to the load and $(1-d)t_s$ time period inductor and source support to the load. In closed loop output voltage of the converter is constant, if the load increases are decreases the current $i_z$ will vary and maintain constant to get desired output voltage. Consider $i_z$ is also one of the control input. $i_g$ is an output when we are taking the DC source as output of the bridge, $i_g$ is normally controlled in unity power factor converters.

The output state equations in both the periods it is same

$$\begin{bmatrix}v_c\\ i_g\end{bmatrix} = \begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{bmatrix}i_l\\ v_c\end{bmatrix}$$

Averaging of state space model during $dt_s$ and $(1-d)t_s$ periods, then resultant state space is averaged large signal model. It has both steady state part and the small deviation part which is away from the equilibrium state.

$d = D + \hat{d}$

$$\begin{bmatrix}\dot{i_l}\\ \dot{v_c}\end{bmatrix} = \begin{bmatrix}0 & -\frac{(1-d)}{L}\\ \frac{(1-d)}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}i_l\\ v_c\end{bmatrix} + \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}[v_g] + \begin{bmatrix}0\\ -\frac{1}{C}\end{bmatrix}[i_z]$$

Output equations after state space averaging are

$$\begin{bmatrix}v_c\\ i_g\end{bmatrix} = \begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{bmatrix}i_l\\ v_c\end{bmatrix} + [0]\,[u]$$

to get the steady state transfer function consider all the derivative terms are zero and the deviations are not considered $\dot{i} = 0$, $\hat{d} = 0$ similarly other deviations consider as zero

$$\begin{bmatrix}0\\ 0\end{bmatrix} = \begin{bmatrix}0 & -\frac{(1-D)}{L}\\ s\frac{(1-D)}{C} & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}I_l\\ V_c\end{bmatrix} + \begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}[\hat{V}_g] + \begin{bmatrix}0\\ -\frac{1}{C}\end{bmatrix}[I_z]$$

$$\begin{bmatrix}V_c\\ I_g\end{bmatrix} = \begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}\begin{bmatrix}I_l\\ V_c\end{bmatrix}$$

$$v_0 = CA^{-1}\begin{bmatrix}\frac{1}{L}\\ 0\end{bmatrix}V_g$$

$$\frac{\hat{v}_o(s)}{\hat{d}(s)} = \frac{v_g}{(1-D)^2}\frac{[1 - s\frac{L}{R(1-D)^2}]}{[1 + s\frac{L}{R(1-D)^2} + s^2\frac{LC}{(1-D)^2}]}$$

(3) The equation (4) is the transfer function of output current to duty ratio

$$\frac{\hat{i}(s)}{\hat{d}(s)} = \frac{v_g}{(1-D)^3}\frac{(2 + sCR)}{[1 + s\frac{L}{R(1-D)^2} + s^2\frac{LC}{(1-D)^2}]}$$

(4) The Simulink model of closed loop single phase boost converter is

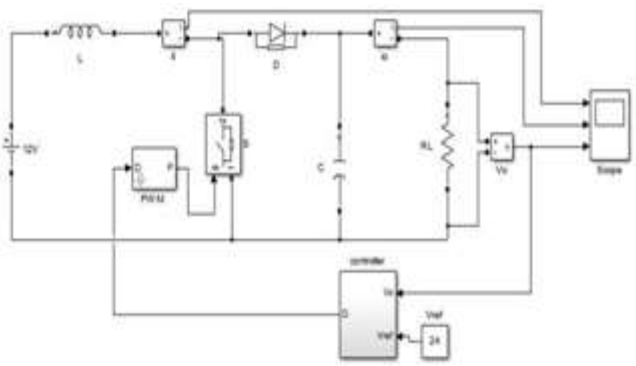


**Fig. 2. Closed loop boost converter**

The steady state T.F is Assume that $i_z = 0$

(1) $$\frac{V_o}{V_g} = \frac{1}{(1-D)}$$

The fig.2 represent the source current ripple in case of
To get the controller transfer functions considers the deviations signals and make the system to be linear

$$\begin{bmatrix} \dot{I_l + \hat{i}_l} \\ \dot{V_c + \hat{v}_c} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{(1-D-\hat{d})}{L} \\ \frac{(1-D-\hat{d})}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} I_l + \hat{i}_l \\ V_c + \hat{v}_c \end{bmatrix}$$

$$+ \begin{bmatrix} \frac{1}{L} & 0 \\ 0 & -\frac{1}{C} \end{bmatrix} \begin{bmatrix} V_g + \hat{v}_g \\ I_z + \hat{i}_z \end{bmatrix}$$

$$\begin{bmatrix} V_c + \hat{v}_c \\ I_g + \hat{i}_g \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} I_l + \hat{i}_l \\ V_c + \hat{v}_c \end{bmatrix}$$

State space model of signal model is

$$\begin{bmatrix} \dot{\hat{i}}_l \\ \dot{\hat{v}}_c \end{bmatrix} = \begin{bmatrix} 0 & -\frac{(1-D)}{L} \\ \frac{(1-D)}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} \hat{i}_l \\ \hat{v}_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L} & 0 & \frac{v_c}{L} \\ 0 & -\frac{1}{C} & -\frac{i_l}{L} \end{bmatrix} \begin{bmatrix} \hat{v}_g \\ \hat{i}_z \\ \hat{d} \end{bmatrix}$$

$$\begin{bmatrix} \hat{v}_c \\ \hat{i}_g \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{bmatrix} \hat{i}_l \\ \hat{v}_c \end{bmatrix}$$

To get the controller transfer function output to input using

$Y(s) = C(sI - A)^{-1}Bu$ (2)

Equation (3) will gives the output control with variation of duty ratio conventional boost converter at duty ratio 0.5082

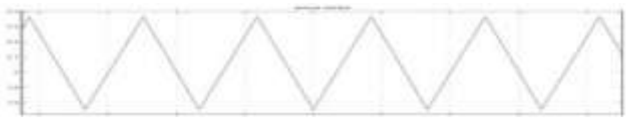


**Fig. 3. Source current ripple in boost**

The output voltage with the variation of input voltage according to controller will change the duty ratio, so the output is almost constant with the specified ripple. Typical values are $V_in = 12$, $v_o = 24v$

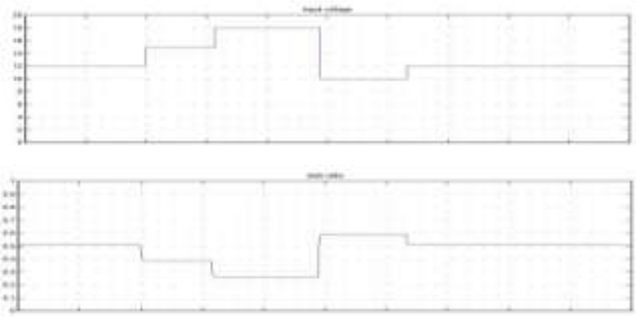


**Fig. 4. Input voltage, duty ratio, output voltage**

## III. Two Phase Boost Converter

Two-phase boost converter shown in fig.5, it has a 180 degree phase shift in both the switches. Consider the required output voltage is 24V and the load is 24ohms, so that the output current is 1A. The inductor current and source current is same the magnitude of average current flowing through the inductor is 2A. The two phase interleaved boost converter source current ripple is less compare with single phase boost converter. The source current ripple of two phase interleaved boost converter is shown in fig.6

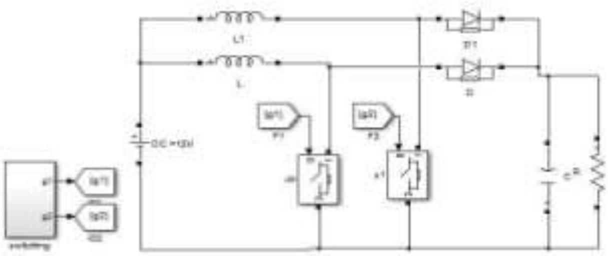


**Fig. 5. Two-phase interleaved boost converter**

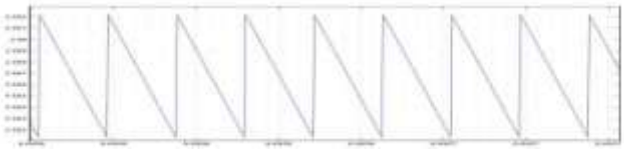
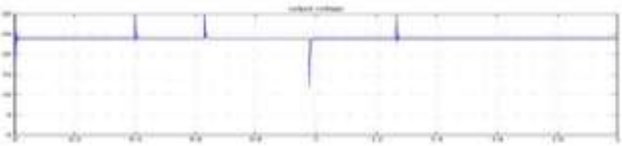


**Fig. 6. Two-phase interleaved boot source current ripple**



The inductor current ripples they are 180 degree phase shift they cancel and produce zero ripple at 0.5 duty ratio. In this case even though the open loop duty 0.5 the closed loop duty ratio is 0.5082 to overcome the losses and produce desired output. So input has very less ripple.

The inductor current ripple

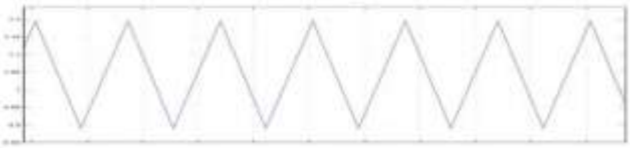


**Fig. 7. Two-phase interleaved boot inductor current ripple**

## IV. FOUR PHASE BOOST CONVERTER

The four phase interleaved boost converter as shown in fig.8, it has an each switch is phase shifted 0, 90, 180, 270 degrees. In four phase interleaved boost converter source current ripple is reduced by four times compare with conventional boost converter. Switching scheme of four phase Interleaved boost is shown in the fig.9. The current flowing through the inductor in N phase interleaved converter is

$$I_L = \frac{I}{N(1-D)} \qquad (5)$$

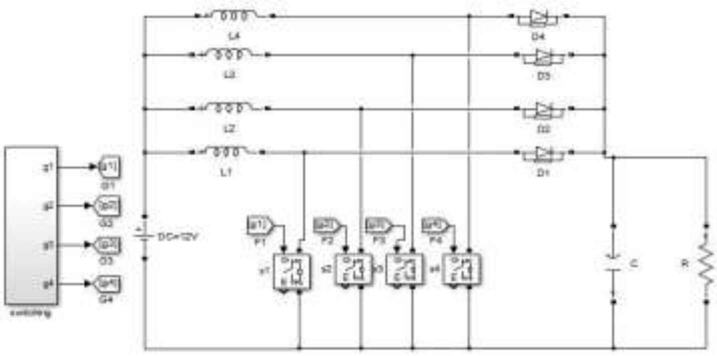


**Fig. 8. Four-phase interleaved boost converter**

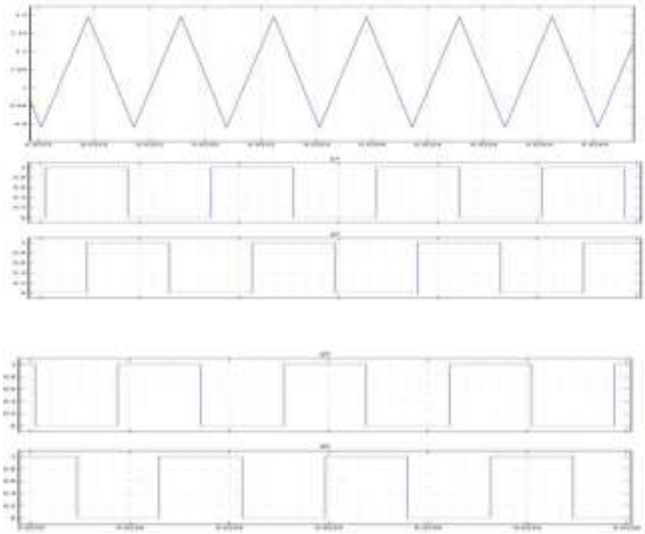


**Fig. 9. Switching scheme for gate signals**

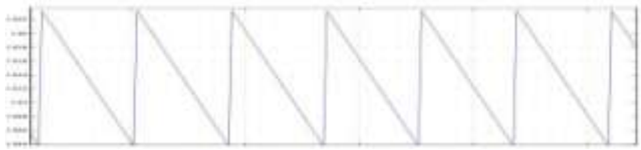


**Fig. 10. Four phase interleaved boost converter source current ripple**

| Converter | Source current ripple (%) |
|---|---:|
| **Single Phase Boost** | **35** |
| **Two Phase Boost Converter** | **10** |
| **Four Phase Boost Converter** | **3** |

## V. CONCLUSION

This work discusses analysis and simulation for single phase boost converter and poly- phase boost converters. The size of N boost converters in parallel is almost same as a single phase boost converter. The smaller RMS current in the energy storage capacitor, lower input ripple current and lower output ripple voltage. The size of the capacitor at the output side is smaller compare to single phase boost converter.

## REFERENCES

[1]. R. T. Naayagi, Andrew J. Forsyth, and R. Shuttlew *High-Power Bidirectional DC-DC Converter for Aerospace Applications* IEEE Transactions on Power Electronics, VOL. 27, NO. II,November,2012.

[2]. M.Arun Devi And K.Valarmathi, *" Ripple Current Reduction in Inter Leaved Boost Converter by Using Advanced PWM Techniques*, IEEE Conference On Advanced Commutation Control And Computing technologies, December 2014.

[3]. Young-Joo Lee And Ali Emadi, *" Phase Shift Switching Scheme for DC/DC Boost Converter with Switches in Parallel* ,IEEE Conference On Vehicle Power and Propulsion Conference (VPPC), September 3-5, 2008, Harbin, China.