Comparision of Transient Performance Analysis of Poly Phase Boost Converter Using PI & PID Controller

Suresh Choudhary, Shiv Shanker Sharma, Devendra kumar Mittal, Jai Prakash

Abstract— **This paper represent the transient performance analysis of poly-phase boost converter and control algorithm which overcomes the problem of high ripple current in the tank capacitor. For the improvement of the functionality of the boost converter there are many methods available among which we consider PI & PID controller in voltage mode control path. Initially we discussed the basic function of the boost converter. Then we derived the transfer function of the complete system. Then we considered model and simulate into matlab without PI &PID controller. Finally we used PI & PID controller in which the values of K_p, K_i & K_d has been derived using the Ziegler-nichols method and loop shaping method. Then we applied the control method on four phase boost converter. At last the output response of the both systems is compared and conclusion made upon that comparison.**

Index Terms— **transfer function of boost converter; closed loop system transfer function; Zieglar-Nichols methodt; Loop shaping method Parallel operation, Poly-phase converter**

I. INTRODUCTION

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. The motivation for this work is expressed through consideration of the above parameters in per unit measured for the two basic converters namely the buck and the boost converter [1]. Consider the boost converter in Fig.1 with per unit values defined as.

V_{dc}=1, D=0.5, T_s=1, E_0=1, P_o=1, $\Delta I_o/I_L$=20%, $\Delta V_o/V_o$=1%

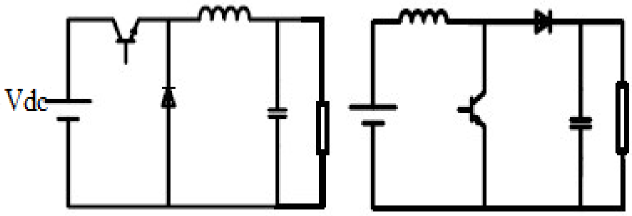

Fig 1 Buck & Boost Converter respectively

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Table I gives the reactive elements and their energy storage capacity for the basic converters. From the table it is obvious that the boost converter requires total energy storage far in excess of buck converter

Table. I: Comparing Buck & Boost Converters (per unit values)

	L (p.u.)	C (p.u.)	V (p.u.)	$\frac{E_i}{P_o T_s}$ (p.u.)	$\frac{E_c}{P_o T_s}$ (p.u.)
BOOST	2.5	12.5	2	1.25	25
BUCK	1.25	10	0.5	1.25	1.25

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. In standard designs it is not uncommon to see tank capacitors one or two orders of magnitude higher than the ideally required capacitance A way to overcome this problem is using poly-phase operation with appropriate phase shift in the control circuit of main switches [2,3]. Fig 2 shows such a poly-phase boost converter (N=4). Fig. 3 shows the conduction intervals of the four switches in the converter. It is seen that at any time at least one of the converters is supplying the load in addition to the capacitor.

The frequency of ripple current in the output capacitor is N times compared to the single stage and therefore the value of the capacitor required can be reduced. The same circuit topology is also applicable to UPF rectifiers [4-6]

In such a scheme, the following advantages are obvious.

- Output capacitor is rated for lower ripple current and higher ripple frequency (nfs).
- Source current has higher ripple and at higher frequency (nfs).
- Another no obvious advantage is that the multi-phase converter may be operated with less number of stages when the load current is low. This will lead to operation under CCM at light load as well as better efficiency

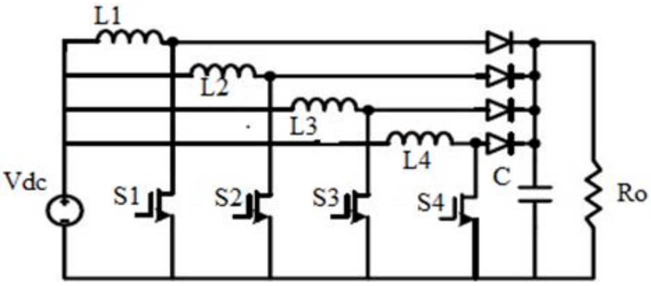


Fig 2 Multi-phase boost Converter(N=4)

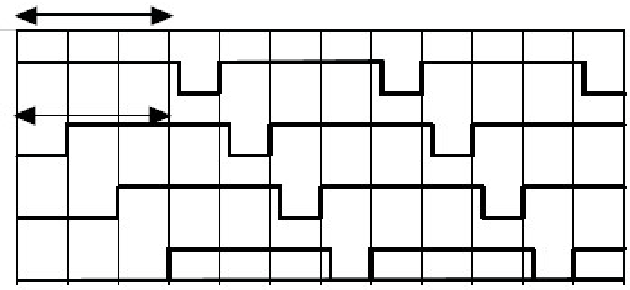


Fig 3 The case with Dmax ≥ 1-1/4

II. MATHEMATICAL MODELING

A. Transfer Function of Boost Converter - Basic circuit of the boost converter is shown in Figure 4

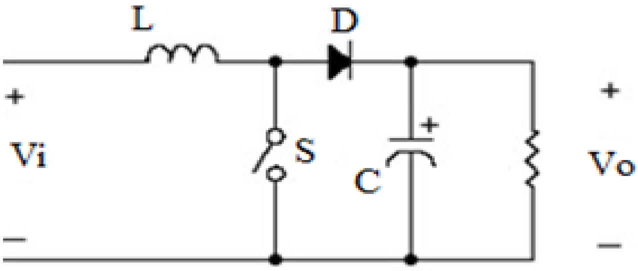


Fig 4 Basic boost converter

Here, L is the inductor, C is the output capacitor and R_L is the resistor which is consider as a load. I_L is the current flow through the circuit. Switch is triggered by the pulse which is generated by PWM technique. Switch remains on during T_{on} cycle and off during T_{off} cycle so triggering is depends on the duty cycle. V_{dc} is the D.C. input voltage supply which is taken from the bridge rectifier which converts A.C. input voltage into D.C., V_o is the output of the boost converter which is larger than the input voltage V_{dc}.

Now to achieve proper objective of converter, it is need to measure and maintain output voltage at required voltage level. So for that purpose it is needed to use feedback loop into the system that is shown in Fig 5

By technique of averaging and linearising small signal model around a operating point the Control-to-output, input to output voltage transfer function for open loop boost converter are obtained as:

$$G_{VVg=}\frac{\hat{v}_o(s)}{\hat{v}_g(s)}=\frac{1}{1-D}\frac{1}{\left[1+s\frac{L}{R(1-D)^2}+s^2\frac{LC}{(1-D)^2}\right]} \quad (1)$$

$$G_{vd}=\frac{\hat{v}_o(s)}{\hat{d}(s)}=\frac{V_g}{(1-D)^2}\frac{1-s\frac{L}{R(1-D)^2}}{\left[1+s\frac{L}{R(1-D)^2}+s^2\frac{LC}{(1-D)^2}\right]} \quad \ldots(2)$$

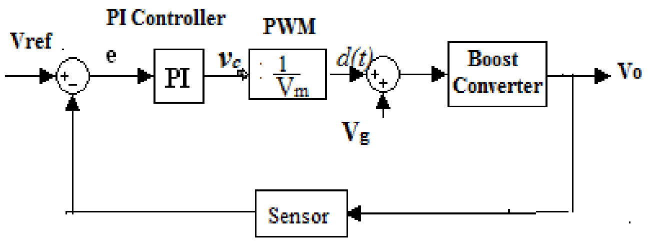


Fig 5 Single Phase Closed Loop System of Converter

Fig 5 shows the close loop control scheme of a boost converter using PI algorithm. Here V_o is compared to V_{ref}. The error signal of the comparator is processed by PI controller and voltage control signal is sent to PWM block, which eventually produce duty ratio. Then it is added with V_{in} which is given to the system

III. SIMULATION

For the simulation purpose I considered the following model:
Input Voltage (dc) :24 volt
Output Voltage (dc) :48 Volt
Boost Inductor (L) :100 mH
Rated Power :100 W
Switching Frequency :100 kHz

Normally, duty cycle for boost converter is considered in between 0.5 to 1. Selection of duty cycle depends on input voltage supply and required output voltage [1]. When boost converter is used without using PI controller it gives steady state error of 25%. So I used PI controller to improve the performance of boost converter. To find out the value of K_p and K_i , I used Ziegler-Nichols step response method and Loop shaping method [4, 5].

Applying step function to the system and analyzing its output response, I got two parameters L = 1 and T = 0.004

Using these, the value of K_p and K_i can be found by Ziegler-Nichols method which is given below.

A. $K_p = 0.0036$ and $K_i = 3.33$

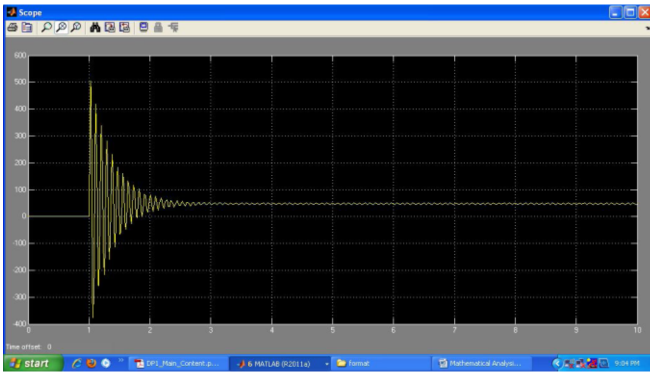
Now, applying these values into PI controller of the closed loop system and simulate it into the matlab I got the response as shown in fig. 6.

From fig. 6 it is shown that it removes steady state error but initially it provide high oscillations.

Now, using the Loop shaping method, eq. 9 and parameter of the considered model I got the following two relation [4 ,5].

$2 * \xi * \omega = (3000 * K_p - 750$……………….(3)

$3000 * K_i = \omega^2$……………………………...(4)



B. Fig. 6 Output Response of system using Ziegler-Nichols Method

For PI controller, ξ is maintained at 0.7 and parameters Kp and Ki must be a larger [6]. So, using eq.3 and eq.4

C. Kp = 0.0104, Ki= 194 & K_d = 5.1385e-07

Now, applying these values into PI, and PID controller of the closed loop system and simulate it into the matlab. The response with both type of controller are found for variable input voltage and variable load. Transient performance in terms of steady state error, settling time and peak overshoot.

IV. Performance Analysis

Transient Performance of PI Controlled Four Phase Close Loop Boost Converters with Variable Input Voltage

Table II Transient Performance of Four Phase Close Loop Boost Converter with Variable Input voltage

S. No.	Input Voltage (volt)	Output Voltage (Volt)	Peak Overshoot	Transient Time (milli-sec)	Steady state error (%)
1	9	48	0	15	0
2	12	48	0	12	0
3	18	48	0	8	0
4	24(rated)	48	0	6	0
5	30	48	56.8	6	0
6	36	48	68.5	8	0
7	42	48	80	10	0
8	48	48	92	50	0

Transient Performance of PI Controlled Four Phase Close Loop Boost Converters with Variable Load

Table III Transient Performance of Four Phase PI Controlled Close Loop Boost Converter with Variable load

S. No.	Load (%)	Output Voltage (Volt)	Peak Overshoot	Transient Time (milli-sec)	Steady state error (%)
1	10	48	0	90	0
2	30	48	0	30	0
3	50	48	0	20	0
4	70	48	0	10	0
5	100	48	0	6	0
6	130	48	0	6	0
7	150	48	0	6	0
8	170	48	0	6	0
9	200	48	0	8	0

V. CONCLUSION

This paper presents analysis of the boost converter using Ziegler-Nichols method and loop shaping method. From the above result, following are the conclusion that can be drawn from this paper.

Using the boost converter without PI controller, it produces steady state error of 25%.

Boost converter used with PI controller applying Ziegler-Nichols method removes steady state error after 2.5 sec. But it produce high oscillation and maximum peak overshoot of 900% that shown in fig. 6. It also produced 14.5% of output ripple. So it is undesirable.

Boost converter used with PI controller applying loop shaping method removes steady state error faster and also removes oscillation which is shown in fig. 7. It also produced only 0.5% output ripple which is lower than the Ziegler-Nichols method.So, from above conclusion can be made that loop shaping method gives better response than the Ziegler-Nichols method for the proposed model

On comparing the performance of single phase and four phase boost converters we found that steady state as well as transient performance of multi phase converter is much superior to single phase. Besides having same size inductor and small size storage multi phase converter can be operated with reduced input current ripple and less output voltage ripple.

From transient analysis it is found that four phase boost converter with PI controller has better performance in terms of transient time and peak overshoot voltage, at all load and input voltage conditions as compared to PID controlled converter. Harmonics are high in at light load in case of PID controller this also increases settling time. Voltage regulation are same at steady stae in both PI as well as PID controlled but high Peak Overshoot in PID controlled converter

VI. FUTURE WORK

The results of this work may be considered for designing the poly phase boost converter for PV cells integrated grid system, boost converter for vehicles and boost converter designed for power factor correction circuit. Further the development of application specific integrated circuit (ASIC) may be explored to provide a smaller, more reliable and cheaper controllers.

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