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Analysis of Boost Converter Using PI Control Algorithms

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***Abstract*-- This paper explains about the boost converter and control algorithm to reduce harmonics. For the improvement of the functionality of the boost converter there are many methods available among which I consider PI controller in voltage mode control path. Initially I discussed the basic function of the boost converter. Then I derived the transfer function of the complete system. Then I considered model and simulate into matlab without PI controller. Finally I used PI controller in which the values of K_p and K_i has been derived using the Ziegler-nichols method and loop shaping method. At last the output response of the both methods is compared and conclusion made upon that comparison.**

Keywords -transfer function of boost converter; closed loop system transfer function; Zigler-Nichols method; loop shaping method.

I. Introduction

Today, most of the equipments are working on dc voltage supply. Normally, the supply coming from power station to the homes, offices, industries etc. is ac supply. So it is needed to convert ac supply into D.C. supply to make useful for the equipment which works on dc. The converter which converts A.C. to D.C. is called ac-dc converter or rectifier. A rectifier is a device used to convert alternating current to direct current (rectification). Rectification is a process of converting an alternating current or voltage into a direct current or voltage. This conversion can be achieved by a variety of circuits based on and using switching devices. The widely used switching devices are diodes, thyristors, power MOS, etc. [1].

Sometimes it is necessary to increases dc voltage. Boost converter is a dc-dc converter in which the output voltage is always greater than the input voltage which depends on switching frequency [1]. Output voltage regulation in the dc-dc converter is achieved by constantly adjusting the amount of energy absorbed from the source and that injected into the load, which is in turn controlled by the relative durations of the absorption and injection intervals. These two basic processes of energy absorption and injection constitute a switching cycle [3].

II. Basic Function of Boost Converter

The DC/DC boost converter only needs four external components: Inductor, Electronic switch, Diode and output capacitor. The converter can therefore operate in the two different modes depending on its energy storage capacity and the relative length of the switching period.

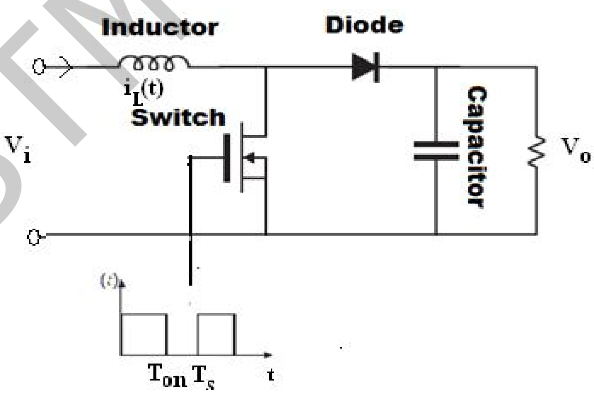

Fig.1 Circuit Schematic of Step-Up dc-dc Converter

Mode 1 begins when IGBT's is switched on at t = 0 and terminates at t = t_{on}. The equivalent circuit for the model is shown in Fig. 1.The inductor current i_L(t) greater than zero and ramp up linearly. The inductor voltage is V_i.

Mode 2 begins when IGBT's is switched off at t = t_{on} and terminates at t = t_s.The inductor current decrease until the IGBT's is turned on again during the next cycle. The voltage across the inductor in this period is V_{in}-V_{out}. In steady state time integral of the inductor voltage over one time period must be zero.

$$V_i * t_{on} + (V_i - V_o) * t_{off} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

V_i : The input voltage, V.
V_o : The average output voltage, V.
t_{on} : The switching on of the IGBT's, sec
t_{off} : The switching off of the IGBT's, sec

Dividing both sides by T_s and rearranging items yield [3].

$$\frac{V_o}{V_i} = \frac{T_s}{t_{off}} = \frac{1}{1-D} \ldots\ldots\ldots\ldots (2)$$

Where,
T_s : The switching period, s.
D : The duty cycle.

III. MATHEMATICAL EXPRESSION

A. Transfer Function of Boost Converter

Basic circuit of the boost converter is shown in Figure 2. Here, L is the inductor and R is the resistor which is consider as a load. I_s 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_{in} is the D.C. input voltage supply which is taken from the bridge rectifier which converts A.C. input voltage into D.C. output voltage. V_{out} is the output of the boost converter which is larger than the input V_{in}.

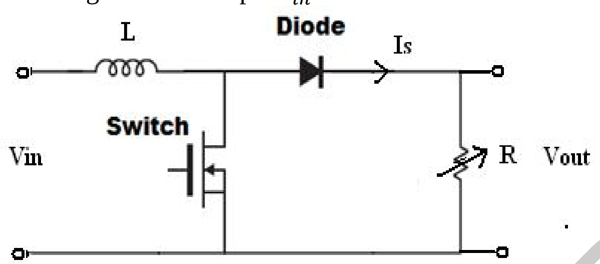

Fig. 2 Basic Circuit of Boost Converter

When switch turns on the current is passing through switch which increases the current level in the inductor. At the end of T_{on} time current stored into the inductor is I_s. So,

$$V_{in} = L * \frac{dI_s}{dt} \ldots\ldots\ldots\ldots (3)$$

Using Laplace Transformation,

$$V_{in}(s) = L * s * I_s(s) \ldots\ldots\ldots\ldots (4)$$

From Figure V_{out} can be given as

$$V_{out}(s) = I_s(s) * R \ldots\ldots\ldots\ldots (5)$$

From equation 4,

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{R}{L*s} \ldots\ldots\ldots\ldots (6)$$

Equation 6 is the basic Laplace transformation equation of the boost converter.

B. Transfer Function of Closed Loop System

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. 3.

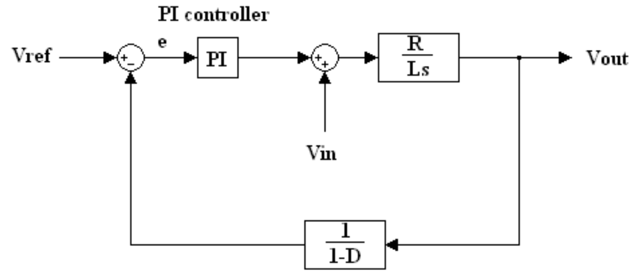

Fig. 3 Closed Loop System of Converter

In this fig. 3 $V_{out}(s)$ is given to the Pulse Width Modulator. The output of the PWM is compared with V_{ref} which is given to the PI controller. Then it is added with V_{in} which is given to the system.

From Figure

$$V_{out} = \left(\frac{R}{L*s}\right) * \left[V_{in} + \left(K_p + \frac{K_i}{s}\right) * e\right] \ldots\ldots (7)$$

Taking $V_{ref} = 0$

$$V_{out} + \left[\left(\frac{R}{L*s}\right) * \left(K_p + \frac{K_i}{s}\right) * \left(\frac{1}{1-D}\right) * V_{out}\right] = V_{in} * \left(\frac{R}{L*s}\right) \ldots\ldots (8)$$

$$\frac{V_{out}}{V_{in}} = \frac{\frac{R}{L*s}}{[1+\{\left(\frac{R}{L*s}\right)*\left(K_p+\frac{K_i}{s}\right)*\left(\frac{1}{1-D}\right)\}]} \ldots\ldots (9)$$

Here, the equation 9 is the transfer function of the closed loop system.

IV. SIMULATION

For the simulation purpose I considered the following model:

Input Voltage (ac)	: 24 volt
Output Voltage (dc)	: 48 volt
Boost Inductor (L)	: 100 mH
Rated Power	: 16 W
Switching Frequency	: 1 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.

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

$$K_p = 0.0036 \text{ and } K_i = 3.33$$

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. 4.

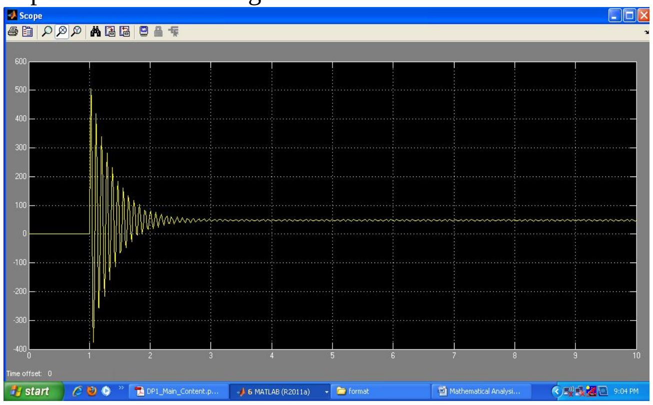

Fig. 4 Output Response of system using Ziegler-Nichols Method

From above fig. 4 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].

$$2 * \xi * \omega = (3000 * K_p) - 750 \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

$$3000 * K_i = \omega^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

For PI controller, ξ is maintained at 0.7 and parameters K_p and K_i must be a larger [6]. So, using eq.10 and eq.11

$$K_p = 2.68 \text{ and } K_i = 13146$$

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. 5.

From the fig. 5 it is shown that it reduce steady state error and it doesn't produce any oscillation which was presented during the Ziegler-Nichols method. The performance of the system is improved by the PI controller using loop shaping method.

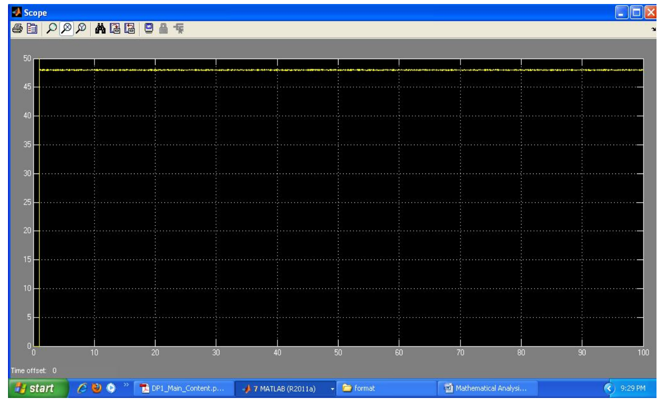

Fig. 5 Output Response of system using Loop shaping Method

V. CONCLUSION

This paper represents 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. 4. 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. 5. 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.

VI. REFRENCES

[1] K.B.Khanchandani , and M.D.Singh, *Power Electronics*, New Delhi:Tata Mcgrawhill, 2005.

[2] Industries, Venable. "Current Mode Control."

[3] Mohammed, B. M Hasaneen, and Adel A. Elbaset. "Design and Simulation of DC-DC Boost Converter," 2008.

[4] Astrom,and Hagglund ,*PID Controllers*,1988.

[5] Copeland, Brain R. "The Design of PID Controllers using Ziegler Nichols Tuning," 2008.

[6] D.P.Eckman, *Automatic Process Control.* New Delhi: Wiley Eastern,1992

[7] Chen Zhou, and M.Jovanovic, "Design Trade-offs in Continuous Current-Mode Controlled Boost Power-Factor Correction Circuit," Virginia, May 1992.

[8] V.K.Mehta and Rohit Mehta, *Principles of Power System*, New Delhi:S.Chand, 2008.

[9] W.Erickson, Robert. "DC-DC Power Converter," *Article in Wiley Encyclopedia of Electrical and Electronics Engineering.*