Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

(Special Issue for ITECE 2016)

Performance Evaluation of Double Boost Converter using PI and PID controller

Chirag P. Suchak[1], Ankit Kumar[2]

[1]ME Student Applied Instrumentation, Atmiya Institute of Technology and Science

[2]Assistant Professor Applied Instrumentation, Atmiya Institute of Technology and Science

Abstract- ***Power converter is critical component in distributed generation system especially for renewable energy system based distributed generators. This paper represents analysis of transient behavior for Double Boost Converter with closed loop control by the use of PI and PID controller. The Converter modelled in MATLAB/Simulink environment. Controlled PWM signal for line variation and load variation is obtained by means of PI and PID controller. A state space average model of the boost converter has been developed and by Ziegler Nichol's method the parameters of PI and PID Controller are obtained. All the simulation results are obtained using MATLAB.***

Keyword-Proportional-Integral (PI), Proportional-Integral-Derivative (PID), Pulse Width Modulation (PWM), Kirchhoff's current law (KCL), Kirchhoff's voltagelaw(KVL)

I. INTRODUCTION

Boost converter is voltage step up and current step down converter, usually used to boost voltage from fixed DC voltage source or Photo Voltaic Cell and to drive load [1]. Double Boost Converter has twice the boost factor compare to traditional boost converter. An increased boost factor suits many applications such as automotive industry, telecommunications industry and IT industry [2]. This paper provides a converter with higher boost factor. PI and PID control strategies are implement to analyze transient behavior for various line disturbance and load disturbance.

II. MATHEMATICAL MODEL

Fig. 1 shows the circuit for Double Boost converter. The inductors L_1 and L_2 having identical values, the diodes D_1-D_3 are the same type and switching element S_1 and S_2 are also identical. Each inductor has its own switch and thus it is similar with the paralleling of two classical Boost Converters. Both inductors are changes in Parallel and discharged in series. Boost converter operates in continuous mode of conduction.

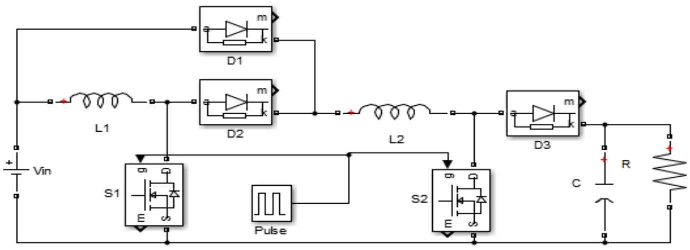

Fig.1 Double Boost Converter model

During derivation of the mathematical model it is to be assumed that all components are ideal. Boost factor of Double boost Converter is given by [1]

$$\frac{V_o}{V_{in}} = \frac{2}{1-d} \quad (1)$$

Where d= duty cycle.

A. *Equivalent Diagram in On State*

When both switches S_1 and S_2 are ON both inductors L_1 and L_2 are charged in parallel by the voltage source (V_{in}) as shown in Fig.2. Both inductors have same current as neglecting the Voltage drop across D_1. Also neglecting the resistance of the switching element when both switches are in ON state. C is the filtering capacitor and R is the load resistance. The value of both inductors are identical so the resultant inductance will be L/2.

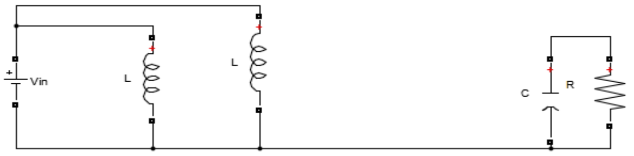

Fig. 2: When both Switches are ON

By applying KVL

$$V_{in}-V_L=0 \quad (2)$$

But as,

$$V_L = \frac{L}{2}\frac{di_L}{dt} \quad (3)$$

By applying KCL at the output side

$$\frac{Vc}{R}+C\frac{dVc}{dt}=0 \quad (4)$$

Rearranging eq. (2) & (4) mathematical model obtained in matrix form as:

$$\begin{bmatrix}\frac{dIL}{dt}\\ \frac{dVc}{dt}\end{bmatrix} = \begin{bmatrix}0 & 0\\ 0 & -\frac{1}{RC}\end{bmatrix}\begin{bmatrix}iL\\ Vo\end{bmatrix} + \begin{bmatrix}\frac{2}{L}\\ 0\end{bmatrix} Vin$$

$$Vo = [0 \quad 1][\begin{matrix}iL\\ Vc\end{matrix}]$$

$$A1= \begin{bmatrix}0 & 0\\ 0 & -\frac{1}{RC}\end{bmatrix} \quad B1= \begin{bmatrix}\frac{2}{L}\\ 0\end{bmatrix} \quad (5)$$

$$C1 = [0 \quad 1] \; D1 = [0 \quad 0] \; (6)$$

B. Equivalent Diagram in OFF State

When both switches S1 and S2 are OFF both inductors L1 and L2 are discharged in series as shown in Fig. 3. As both inductors are in series the resultant inductor will be $2L$.

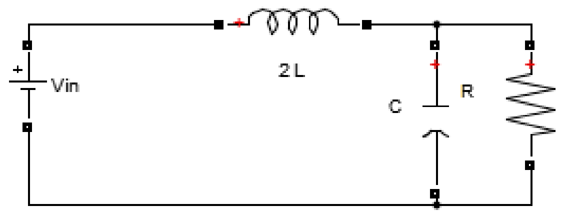

Fig. 3: When both Switches are OFF

By applying KVL

$$\mathrm{VL} = \mathrm{Vin} - \mathrm{Vo} \; (7)$$

But,

$$\mathrm{VL} = 2\mathrm{L}\,\frac{\mathrm{diL}}{\mathrm{dt}} \; (8)$$

$$\frac{diL}{dt} = -\frac{1}{2L}Vo + \frac{1}{2L}Vin \quad (9)$$

By applying KCL

$$iL - \frac{Vo}{R} - C\frac{dVo}{dt} = 0 \quad (10)$$

Rearranging eq. (9) & (10), model obtained in matrix form as:

$$\begin{bmatrix} \frac{dIL}{dt} \\ \frac{dVc}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -\frac{1}{2L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} iL \\ Vo \end{bmatrix} + \begin{bmatrix} \frac{1}{2L} \\ 0 \end{bmatrix} Vin$$

$$A2 = \begin{bmatrix} 0 & -\frac{1}{2L} \\ \frac{1}{C} & -\frac{1}{RC} \end{bmatrix} \quad B2 = \begin{bmatrix} \frac{1}{2L} \\ 0 \end{bmatrix} \quad (11)$$

$$C2 = [0 \quad 0] \quad D2 = [0 \quad 0] \quad (12)$$

By using the state space averaging technique the averaged matrices are obtained as:

$$A = A_1 * d = (1-d) * A_2$$
$$B = B_1 * d = (1-d) * B_2$$
$$C = C_1 * d = (1-d) * C_2$$
$$D = D_1 * d = (1-d) * D_2$$

So, the final resultant matrices are

$$A = \begin{bmatrix} 0 & -\frac{(1-D)}{2L} \\ \frac{(1-D)}{C} & -\frac{1}{RC} \end{bmatrix} \quad B = \begin{bmatrix} \frac{(3D+1)}{2L} \\ 0 \end{bmatrix} \quad (13)$$

$$C = [0 \quad 1] D = [0 \quad 0] \quad (14)$$

The control transfer function for the voltage controlled Double Boost converter is defined as the ratio of output voltage to duty cycle as it is obtained by the formula [2]

$$\frac{VO(S)}{d(s)} = C * (SI-A)^{-1} * (A1-A2) * X \quad (15)$$

Where $X = -A^{-1} * B * V_{in}$

Transfer function obtained can be utilized to find the K_p, K_i and K_d for controller.

III. CONTROLLER PARAMETER TUNING

As the characteristics of power sources and electrical loads become more widely varied and unpredictable, the control of the power converters that provide the necessary power processing function will play an important role in optimizing performance and maintaining the needed robustness under various operating conditions.

A. Ziegler Nichols Method of Tuning the PI and PID controller

The Ziegler-Nichols tuning method is a heuristic method of tuning PI and PID controller. It is performed by setting the I (Integral) and D (Derivative) gains to zero. The P (Proportional) gain K_p is the increased until it reaches the ultimate gain(K_u), at which the output of the control oscillates with a constant amplitude and the oscillation periods(P_u) are used to set the P, I and D gains depending on the type of controller.

Table1. ZIEGLER NICHOLS METHOD

Controller Type	Proportional Gain (Kp)	Integral Gain(Ki)	Derivative Gain(Kd)

PI	$0.45K_u$	$1.2Kp/P_u$	
PID	$0.6K_u$	$2Kp/ P_u$	$K_p P_u /8$

Using the above table values of the K_p,K_i and K_d for PI and PID can be derived using Ziegler Nichols Method.

B. Design and Simulation for the Double Boost Converter

Consider the components values listed in the below table for designing the Double Boost Converter.

Table 2. DOUBLE BOOST CIRCUIT PARAMETER

Parameter	Symbol	Value
Input Voltage	Vin	12V D.C.
Output Voltage	Vo	48V D.C.
Input Inductors	L1,L2	100µH
Output Capacitor	C	10µ
Load Resistance	R	50Ω

Using the parameter value listed in above table for the duty cycle (d) =0.5, putting the values in equations (14) Linear Time Variant transfer function can be achieved. Fig.4 represents the step response for d=0.5.

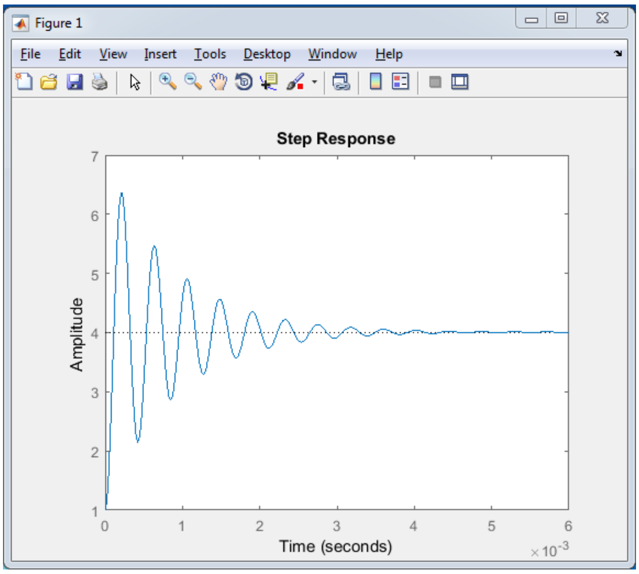

Fig.4 Step Response for Double Boost Converter

C. PI Close loop Control

PI control is the simplest control applied for the Double Boost converter. Using the values K_p and K_i and creating a close loop for the converter as shown in Fig.5, simulation can be carried out for Line Variation and Load Variation.

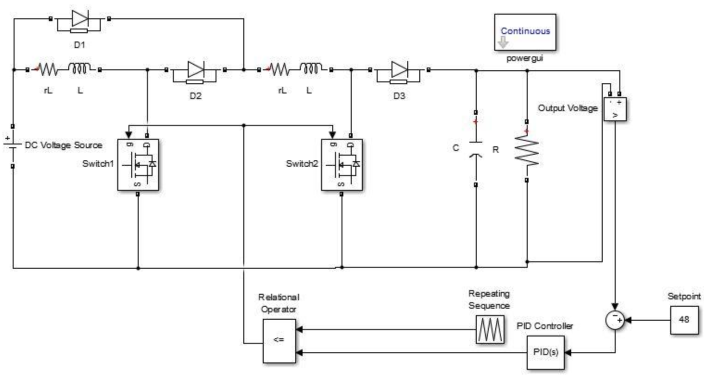

Fig. 5 Close Loop Control for Double Boost Converter

In the case of power converter it is generally observed that there is variation at Load side hence it is important that the Output voltage should be maintained near to desired values irrespective to load variation. During the simulation it is assumed that the normal operating input voltage is 12V and normal operating load is 50Ω.

For Double Boost converter set point is arranged at 48V DC. To find out ultimate gain Ku and Oscillation period Pu, first of all Integral gain (I) and Derivative Gain (D) is set to zero and slowly increasing the Proportional gain from zero (0).

The resultant values obtained are: Ku=0.00833 and Pu=0.00295. Hence according to Table I.

Table 3. PI and PID gains values

Controller Type	Proportional Gain (Kp)	Integral Gain(Ki)	Derivative Gain(Kd)
PI	0.00375	1.525424	----------
PID	0.005	3.3898	1.843×10^{-6}

For maintaining output voltage at 48V, PI controller is implemented. Close loop response of circuit using PI controller is varied again load change from 40Ω to 60Ω and transient response parameters are observed as shown in Table 4

Table 4. PI Controller for Load Variation

	K_p=0.00375	K_i=1.5254		
Supply Voltage V_i=12V DC				
Load Resistance R (Ω)	Load Current (A)	Load Voltage V_0 (V)	Peak Overshoot (V)	Settling Time (mS)
40	1.207	48.262	48.997	19.981
42	1.145	48.104	49.338	19.983
44	1.097	48.285	49.523	19.994
46	1.032	47.464	49.700	20.001
48	1.003	48.147	49.893	19.984
50	0.965	48.285	50.036	19.989
52	0.921	47.943	50.202	19.971
54	0.890	48.016	50.373	19.274
56	0.861	48.248	50.522	19.978
58	0.825	47.901	50.689	16.387
60	0.800	48.042	50.838	18.088

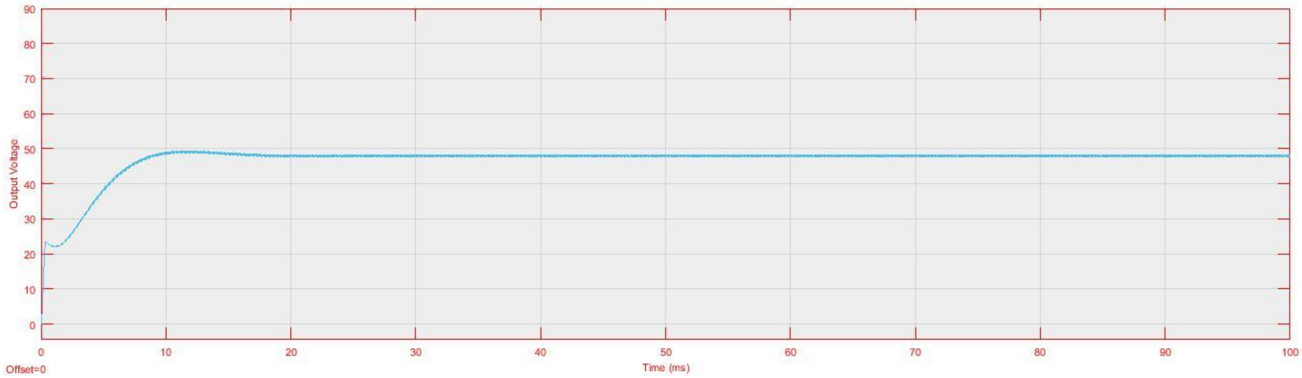

Fig.6 Close Loop for R_L =50Ω for Double Boost Convertor for PI Controller

Figure 6 shows that required set point value is achieved using PI controller

For load variation it is observed that, as the load value increases peak overshoot and settling time for the system increases.

Similarly for Load Variation from 9V Dc to 12V DC.

Table 5. PI Controller for Line Variation

Load resistance Value R_L=50Ω			
	K_p=0.00375	K_i=1.5254	
Line Voltage V_i(V)	Load Voltage V_0 (V)	Peak Overshoot (V)	Settling Time (mS)
9	48.028	48.760	19.990
10	48.422	48.665	19.989
11	48.106	49.340	19.291
12	48.285	50.036	19.989

As in the case of line variation the peak overshoot increases as line voltage increases but the settling time remains nearby same for entire line variation operation.

D. PID Controller

Analyzing the results available from PI controller, it is found that the value of Peak Overshoot and Settling time is somewhat higher. To reduce the value of the Peak Overshoot and Settling time PID controller can be used. PID controller having advantage over PI controller that it provides speedy response compare to PI controller. This speedy action is achieved due to D term.

For maintaining output voltage at 48V, PI controller is implemented. Close loop response of circuit using PID controller is varied again load change from 40Ω to 60Ω and transient response parameters are observed as shown in Table 6.

Table 6. PID Controller for Load Variation

Supply Voltage V_i=12V DC				
	K_p=0.005	K_i=3.3898	K_d=1.8437x10-^{6}	
Load Resistance R (Ω)	Load Current (A)	Load Voltage V_0 (V)	Peak Overshoot (V)	Settling Time (mS)
40	1.203	48.133	48.375	19.984
42	1.146	48.130	48.371	19.962
44	1.094	48.125	48.367	18.902
46	1.046	48.124	48.366	18.202
48	1.003	48.125	48.366	17.502
50	0.962	48.132	48.373	17.001
52	0.925	48.139	48.381	16.501
54	0.891	48.144	48.386	16.000
56	0.859	48.149	48.391	15.600
58	0.83	48.168	48.410	15.200
60	0.802	48.170	48.412	14.799

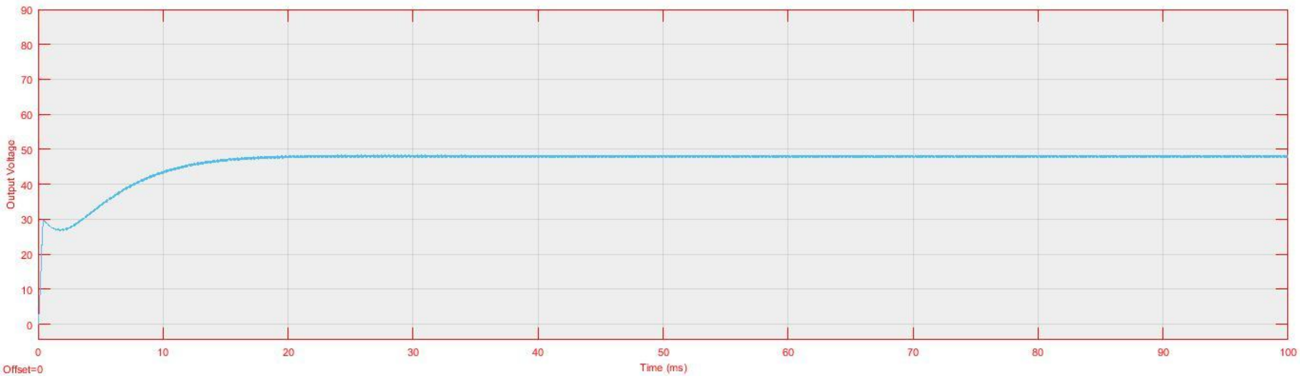

Fig.7Close Loop for R_L =50Ω for Double Boost Convertor using PID Controller

Figure 7. shows the closed loop response for Double boost converter using PID controller in which it can be observed that settling time reduces compare to PI controller response.

Comparing the result for PID controller with PI controller result it is seen that there is substantial reduction in the peak overshoot as well reduction in the settling time of the system.

Similarly for Load Variation from 9V Dc to 12V DC.

Table 7. PID Controller for Line Variation

Load resistance Value R_L=50Ω			
	K_p=0.005	K_i=3.3898	K_d=1.8437x10-^{6}
Line Voltage V_i(V)	Load Voltage V_0 (V)	Peak Overshoot (V)	Settling Time (mS)
9	47.729	48.456	19.989
10	48.141	48.383	19.084
11	48.143	48.385	18.271
12	48.132	48.373	17.001

IV. CONCLUSION

This paper presents transient analysis of Double boost converter with closed loop control by PID controller. In many industrial application it is required to boost the voltage and maintain the output voltage constant. By applying the Ziegler Nicholas method of tuning for PI and PID controller was designed to overcome effect of line variation and load variation on the converter system. By analyzing the transient response of PI controller and PID controller, it is concluded that the PID controller is more effective compare to PI controller. Because it reduces the peak overshoot and takes less time for system to be stable.

REFERENCES

[1]. JFJ van Rensburg Vaal University of Technology, Faculty of Engineering & Technology, P. Bag X021, Vanderbijlpark, 1900, South Africa, MJ Case and DV Nicolae University of Johannesburg, Power & Control Engineering Technology, PO Box 17011, Doorfontein 2028, Johannesburg, South Africa "Double boost DC to DC converter", Industrial Electronics, 2008. IECON 2008. 34th Annual Conference of IEEE

[2].LopamudraMitra&Nibedita Swain Electrical and Electronics, Silicon Institute of Technology Silicon Institute of Technology Bhubaneswar, "Closed Loop Control of Solar Powered Boost Converter with PID Controller" India 2014 IEEE International Conference on Power Electronics, Drives and Energy Systems

[3]Mohammad Shahrokhi and AlirezaZomorrodi " Comparison of PID ControllerTuning Methods"Department of Chemical & Petroleum Engineering Sharif University of Technology.

[4] Jorge Alberto Morales-Saldaña, Roberto Galarza-Quirino, Jesús Leyva-Ramos,Member IEEE, "Modeling and Control of a Cascaded Boost Converter with a Single Switch" The 32nd Annual Conference of the IEEE Industrial Electronics Society, 2006