# Improved Performance of KY Positive Output Boost Converter using Classical PI Controller

**K.Ramash Kumar, S. Balakumar, S. Azath Hussain**

***Abstract:** This paper studies on modeling, simulation with output potential control of KY-POBC using proportional integral controller (PIC). Due to time varying and switching characteristics of KY-POBC and also its dynamic performance is complex. Owing to increase the dynamic characteristics with output potential control of KY-POBC, a PIC is designed. The dynamic equation of the KY-POBC is derived with help of averaging method at first and then PIC is developed using Zeigler-Nichols Tuning method. The analysis of designed controller is verified at different operating conditions via. the transient region, supply voltage variation and the load variation by making MATLAB/Simulink model. The results are showed designed controller proficiency performance at various working regions.*

***Keywords:** Boost converter, PIC, and KY converter.*

## I. INTRODUCTION

In much low power source application needs good output voltage with minimal ripple voltage. Current days, low ripple voltage-stepping converter topologies is well presented [1-2]. But, these converters have one right-half plane zero (RHPZ) in continuous coil current that is complex in real time implementation. The KY-boost converter has currently established by K.I. Hwu and Y.T. Yau works in continuous current whereas maintaining load current is not pulsating that make the less rate of change of voltage across output capacitor resulting the low load voltage ripples in the range of mV and in addition a very good transient response in the order of few mS [3]. The state space average model for various DC-DC converters was addressed [4]. The PI and SM controllers for various DC choppers were reported [5-14].

Therefore, in this paper, it is designed to control output voltage of KY positive output boost converter (POBC) operated in continuous coil current with the proportional integral controller (PIC). The average model of the KY-POBC is derived at first and then PIC is designed. The performance of controller using KY-POBC is validated at different regions.

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## II. OPERATION AND STATE SPACE AVERAGE MODEL OF KY POSITIVE OUTPUT BOOST CONVERTER

The KY-POBC (refer the Fig.1). The KY-POBC is DC-DC converter operating with voltage conversion ratio of 1 plus d, where‘d’ is the time variant duty cycle of the PWM signal which is controlled by the output voltage of it. It consist of twice coils, $S_1$ and $S_2$ with $D_1$, and $D_2$ and $D_b$ with $C_b$ and $L_i$ and $L_0$ with $C_0$. The KY-POBC is operating with state 1 and state 2.

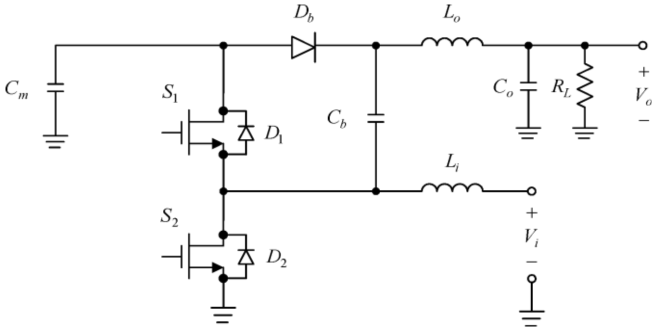

**Fig. 1 Topology of KY boost converter**

The power flow circuit of the state 1 KY POBC (see fig.2).

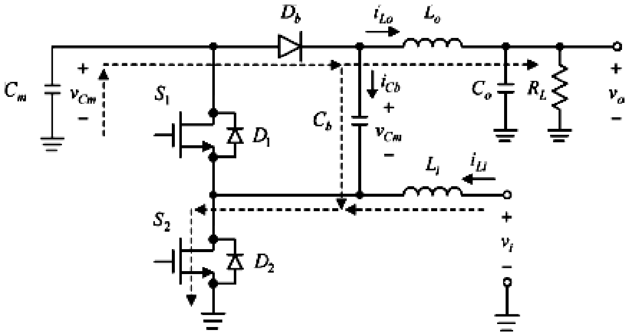

**Fig. 2 Equivalent circuit of state 1 operation**

In state 1, switch $S_1$ is open and $S_2$ is closed which ground the negative terminal of $C_b$ is pulled to the ground that leads to $D_b$ conduct. In this mode, $C_m$ is released energy and $C_b$ is charged. The $V_{Li} = V_{i,}$ $L_i$ is stored the energy and $L_0$ is released energy. The $i_{cm} = i_{cb} + i_{Lo.}$ $i_{co} = i_{Lo} + i_{o.}$ The state 1 working is expressed by the state equations as (1)

$$L_i\frac{\partial i_{Li}}{\partial t} = V_i$$
$$L_0\frac{\partial i_{Li}}{\partial t} = V_{cm} - V_o$$
$$C_0\frac{\partial v_o}{\partial t} = i_{Lo} - \frac{V_o}{R_L}$$
$$C_m\frac{\partial v_{cm}}{\partial t} = -i_{cb} - i_{Lo} \qquad (1)$$

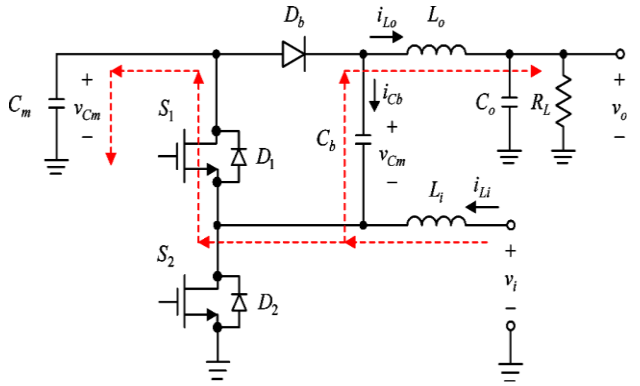

**Fig. 3 Equivalent circuit of state 2 operation**

In this mode 2 operation (refer Fig.3) $S_1$ is closed and $S_2$ is open that make $D_b$ in reverse biased and stores $C_m$ and release the energy $C_b$. The voltage across $V_{Li} = V_i - V_{cm}$ that $L_i$ de-energized and $L_0$ energized, since the voltage across inductor $V_{Lo} = 2V_{cm} - V_0$. The $i_{cm} = i_{Lo} - i_o$. The $i_{cm} = i_{Li} - i_{Lo}$. The mode 2 working is expressed by (2)

$$L_i\frac{\partial i_{Li}}{\partial t} = V_i - V_{cm}$$
$$L_0\frac{\partial i_{Lo}}{\partial t} = 2V_{cm} - V_o$$
$$C_0\frac{\partial v_o}{\partial t} = i_{Lo} - \frac{V_o}{R_L}$$
$$C_m\frac{\partial v_{cm}}{\partial t} = i_{Li} - i_{Lo} \qquad (2)$$

The mean value of voltage and current can be found from (3), where the variable x is the time-varying parameter and symbolizes voltage or current.

$$\langle x \rangle = \frac{1}{T_s}\int_0^{T_s} x\,d\tau \qquad (3)$$

The average equation found from (1)-(3) are expressed by (4)

$$L_i\frac{\partial\langle i_{Li}\rangle}{\partial t} = \langle V_i\rangle - (1-d)\langle V_{cm}\rangle$$
$$L_0\frac{\partial\langle i_{Li}\rangle}{\partial t} = (2-d)\langle V_{cm}\rangle - \langle V_o\rangle \qquad (4)$$
$$C_0\frac{\partial\langle V_o\rangle}{\partial t} = \langle i_{Lo}\rangle - \frac{\langle V_o\rangle}{RL}$$
$$C_m\frac{\partial\langle V_{cm}\rangle}{\partial t} = -\langle i_{Lo}\rangle + (1-d)\langle i_{Li}\rangle - d\langle i_{cb}\rangle$$

The voltage transfer gain of KY POBC is expressed as (5)

$$\frac{V_o}{V_i} = \frac{2-d}{1-d} \qquad (5)$$

Let us choose the state variables of KY-POBC as $i_{Li} = X_1, i_{Lo} = X_2, V_o = X_3, V_{cm} = X_4$ and its differential equation for the state operation of mode 1 KY-POBC is given as

$$\dot{X}_1 = \frac{V_i}{L_i}$$
$$\dot{X}_2 = \frac{X_4}{L_o} - \frac{X_3}{L_o}$$
$$\dot{X}_3 = \frac{X_2}{C_o} - \frac{X_3}{C_o L_o}$$
$$\dot{X}_4 = \frac{-X_2}{C_m + C_b} \qquad (6)$$

The differential equation for the state operation of Mode 2 KY-POBC is expressed as,

$$\dot{X}_1 = \frac{V_i}{L_i} - \frac{X_4}{L_i}$$
$$\dot{X}_2 = \frac{2X_4}{L_o} - \frac{X_3}{L_o}$$
$$\dot{X}_3 = \frac{X_2}{C_o} - \frac{X_3}{R_L C_o}$$
$$\dot{X}_4 = \frac{X_1}{C_m} - \frac{X_2}{C_m} \qquad (7)$$

By applying the above equations, the average model of the given system is derived by using the equation (8),

$$\dot{X} = [A_{on}d + A_{off}(1-d)] + [B_{on}d + B_{off}(1-d)]$$
$$Y = [C_{on}d + C_{off}(1-d)] \qquad (8)$$

Where,

$$[A_{on}d + A_{off}(1-d)] = A$$
$$[B_{on}d + B_{off}(1-d)] = B$$
$$[C_{on}d + C_{off}(1-d)] = C \qquad (9)$$

The matrix equation for the A, B, C parameters are given as follows,

$$A = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{-d}{L_o} & \frac{d}{L_o} \\ 0 & \frac{d}{C_o} & \frac{-d}{C_o R_L} & 0 \\ 0 & \frac{-d}{C_m + C_b} & 0 & 0 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & 0 & \frac{-1+d}{L_i} \\ 0 & 0 & \frac{-1+d}{L_o} & \frac{2-2d}{L_o} \\ 0 & \frac{1-d}{C_o} & \frac{-1+d}{C_o R_L} & 0 \\ \frac{1-d}{C_m} & \frac{-1+d}{C_m} & 0 & 0 \end{bmatrix} \qquad (10)$$

$$C = \begin{bmatrix} 0 & 0 & 0 & 1 \end{bmatrix}$$

## III. DESIGN OF PIC

The PIC is developed to guarantee the identifying the aspiration nominal working for the KY-POBC. By regulating the KY-POBC, with the intention that it stays very closer to the nominal working point in the case of R variations, elements variations and also, for line variations.

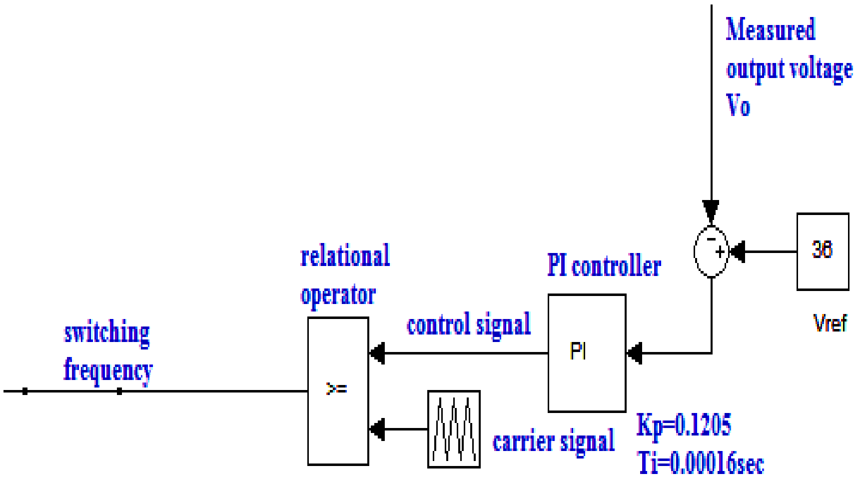

**Fig. 4 Design of PIC**

The PIC design has proportional gain ($K_p$) and Integral time (Ti) are designed using Zeigler-Nichols tuning method. Zeigler-Nichols suggested to mark the ranges of $K_p = 9.316$ and $T_i$=0.0166s according to Table 1 suggested by Zeigler-Nichols method [14]. Simulink diagram of PIC is shown in Fig. 4.

**Table. 1 Zeigler Nichols Tuning Method**

| PID Type | $K_p$ | $T_i$ | $T_d$ |
|---|---|---|---|
| P | $0.5K_{cr}$ | $\infty$ | 0 |
| PI | $0.45K_{cr}$ | $\frac{P_{cr}}{1.2}$ | 0 |
| PID | $0.6K_{cr}$ | $\frac{P_{cr}}{2}$ | $\frac{P_{cr}}{8}$ |

## IV. SIMULATION STUDY

The verification of KY-POBC with controller is done for different regions using MATLAB/Simulink (refer fig. 5). A simulation has been performed on the KY-POBC with the parameters listed in Table 2.

**Table. 2** Specification of KY-POBC

| PARAMETERS | SYMBOL | VALUE |
|---|---|---|
| Input voltage | $V_i$ | 12V |
| output voltage | $V_o$ | 36V |
| Rated load current | $I_o$ | 2.5A |
| Output inductance | $L_o$ | 15μH |
| Input inductance | $L_i$ | 15μH |
| Buffer capacitance | $C_m$ | 1000 μF |
| Energy transferring capacitor | $C_b$ | 680 μF |
| Output capacitance | $C_o$ | 470 μF |
| load | $R_L$ | 14.4 |
| Switching frequency | $f_s$ | 100kHZ |

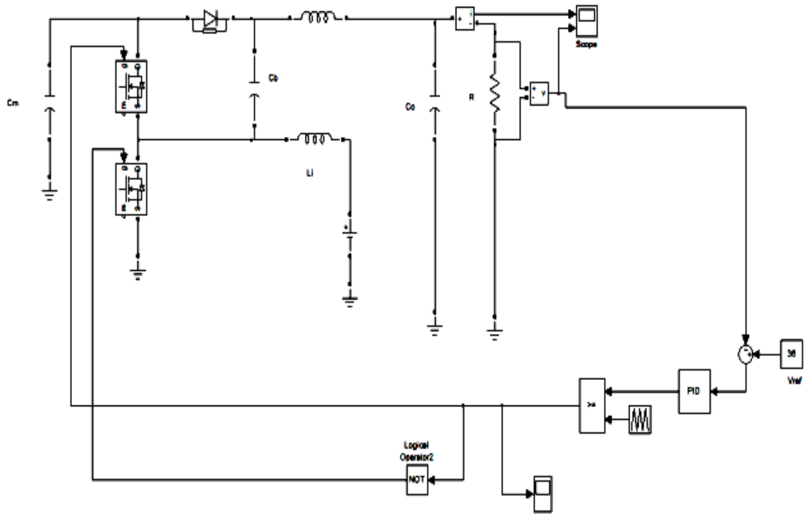

**Fig. 5 MATLAB/Simulink model PIC for the KY-POBC**

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### A. Transient Region

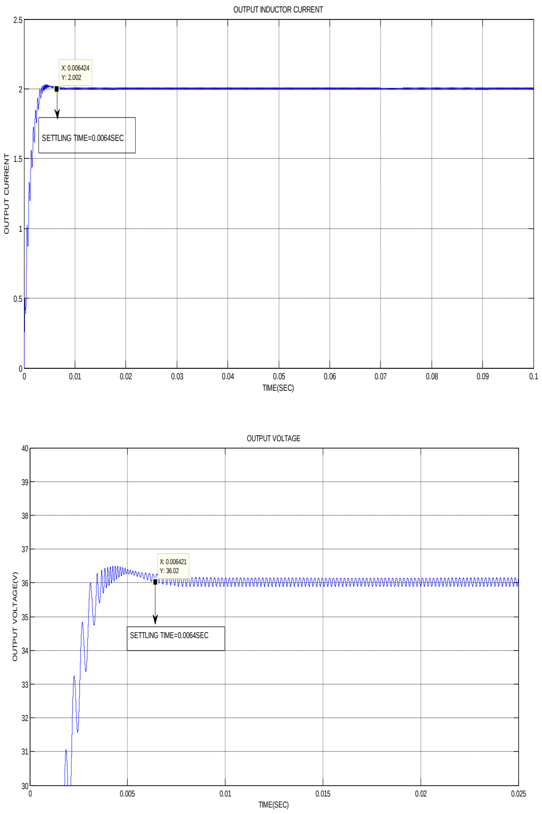

**Fig. 6 Simulated results of KY-POBC using PIC, (a) inductor current, and (b) output voltage in a transient region.**

Fig.6 (a) and (b) shows the output voltage and the inductor current of PI with KY positive boost converter in transient region. It can be seen that KY-POBC has negligible peak overshoot and settling time of 0.0064 sec.

### B. Line Variations

Fig.7 shows the simulated output voltage of KY-POBC with control for the input voltage from 12V to 15V. It is found that KY-POBC has maximum overshoot of 1.13 V and settling time of 0.0041 s with PIC.

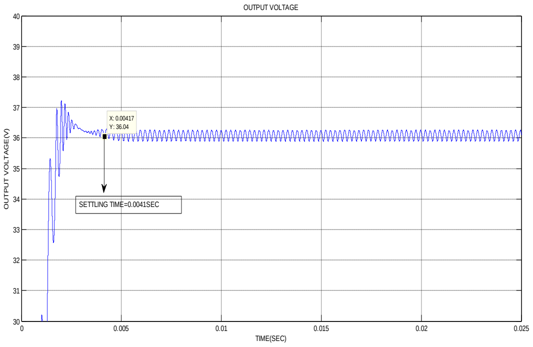

**Fig. 7 Simulated output voltage of the converter using PIC when input takes step change to 12V to 15V.**

### C. Load Variations

Fig.8 shows the simulated output voltage with R from 18 Ω to 28 Ω. It is found that KY-POBC has overshoot of 0.4V and time of 0.006 sec.

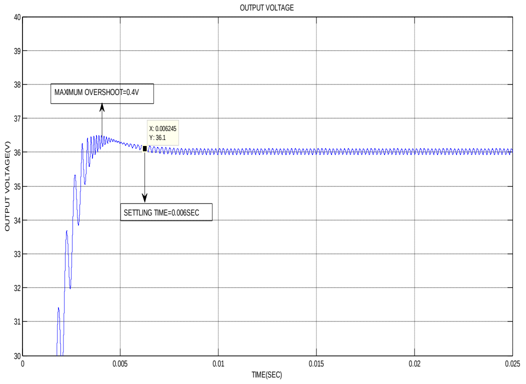

**Fig. 8 Simulated output voltage of KY-POBC using PIC for load resistance step change from 18 Ω to 28 Ω**

In Fig.9 shows that variation of output with step change from 18 Ω to 12 Ω. It could be seen that there is a small overshoot of 0.52V with settling time of 0.006 sec.

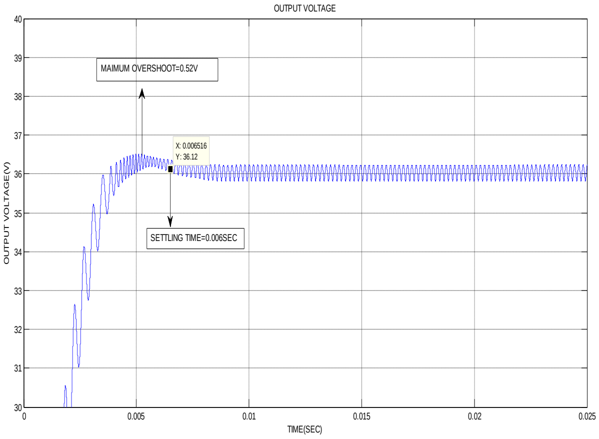

**Fig. 9 output voltage of load resistance varies from 18 Ω to 12 Ω.**

## V. CONCLUSIONS

In this paper modelling, simulation and load voltage control of KY-POBC with PIC has been successfully demonstrated using MATLAB/Simulink. Numerical analysis and simulations are presented to show the proficient of designed PIC for the KY-POBC operated resulted in proficient regulated output voltage in line and load disturbances, good steady state and transient responses etc. It is, therefore, suitable for any stable power source real-world commercial applications.

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