

# Design and Simulation of Full-Bridge Isolated Boost dc-dc converter in MATLAB using PI Controller

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**ABSTRACT:** This paper presents simple approach for DC voltage control using isolated dc-dc full-bridge converter. This topology is used for stepping up the DC voltage at required level using step-up transformer. In this topology 24V dc voltage is converted into 48V dc in MATLAB in open loop. The closed loop simulation using PI controller is also performed in MATLAB.

**KEYWORDS:** dc-dc boost full-bridge converter, State-space analysis, PI controller, MATLAB/SIMULINK.

## 1. Introduction

In this paper, The full bridge DC/DC converter is proposed which is suitable for high-power transmission because switch voltage and current are not high. It has small input and output current and voltage ripples. Full-bridge converter which has the possibility to high voltage step-up because of its High frequency transformer. The isolated boost full bridge converter will convert the 24V DC to 48V DC. A full-bridge converter drive consists of four power switches, isolation step up transformer, full-bridge circuit of diode (rectifier), filter (inductor and capacitor), and resistor at load side.

## 2. Operation Principle of DC-DC Full-bridge converter

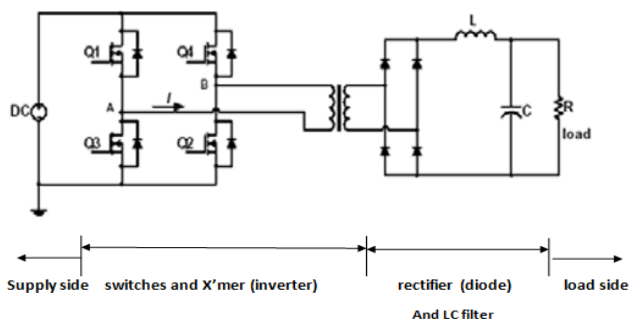


figure 1: dc-dc full-bridge converter

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This topology consists of four main circuit elements: a power switches, transformer, rectifier diode and LC filter. The power switches, which can be either a transistor or MOSFET, used to control flow of energy. A transformer is placed to provide DC isolation between input and output and also perform stepping up operation of input voltage. The rectifier diode and LC filter form energy transfer mechanism to supply energy for maintaining voltage and current at required level at load side.

The diagonally opposite switches ( $Q_1$  and  $Q_2$ , or,  $Q_3$  and  $Q_4$ ) are turned on and off simultaneously in portion of each half cycle of switching frequency (for time interval  $D \cdot T$ ). When all four switches are turned off, the load current freewheels through the rectifier diode (for time interval  $(0.5-D) \cdot T$ ). The PWM pulse generator has input of duty cycle ( $D$ ) and will produce appropriate pulses and sends them to switches.

There are four modes of operation:

- 1) When switches  $Q_1$  and  $Q_2$  are ON.
- 2) When all switches are OFF.
- 3) When switches  $Q_3$  and  $Q_4$  are ON.
- 4) When all switches are OFF.

**MODE 1:** when switches  $Q_1$  and  $Q_2$  are ON.

Here, switches  $Q_1$  and  $Q_2$  are ON so that voltages across switches  $Q_1$  and  $Q_2$  are:

$$V_{Q1} = 0 \text{ and } V_{Q2} = 0$$

The primary winding voltage is given by,  $V_p = V_{dc}$  and secondary winding voltage,  $V_s = \left(\frac{N_s}{N_p}\right) * V_{dc}$

Here, voltage across inductor is given by,  $V_l = V_s - V_o$

$$\text{So, } L * \left( \frac{di_L}{dt} \right) = \left( \frac{N_s}{N_p} \right) * V_{dc} - V_0$$

At the end of mode 1,  $dt = T_{on} = DT$  where, (D = duty cycle, T = total time period)

$$\text{So, } \Delta I_L = \frac{V_L * DT}{L} \text{ and } \Delta I_p = \frac{V_{dc} * DT}{L}$$

**MODE 2:** when all switches are OFF.

As all switches are OFF, transformer changes its polarity and load current flow through bridge diodes.

$$\text{For that here, } V_s = V_p = I_p = 0 \text{ and } I_s = \frac{I_L}{2}$$

Now, voltage across inductor is,  $V_L = V_0$

$$\text{So, } L * \left( \frac{di_L}{dt} \right) = V_0$$

At the end of mode 2,  $dt = T_{OFF} = (0.5-D)*T$

$$\text{So, } \Delta I_L = \frac{V_0 * (0.5-D) * T}{L}$$

**MODE 3:** when switches  $Q_3$  and  $Q_4$  are ON.

At this mode, operation is similar to the mode 1 but voltage polarity of primary and secondary will be changed.

**MODE 4:** when all switches are OFF.

The operation of this mode is identical to mode 2. Now, comparing the equation of  $\Delta I_L$  from mode 1 and mode 2, we have,

$$V_L * D = V_0 * (0.5-D)$$

$$\left[ \left( \frac{N_s}{N_p} \right) * V_{dc} - V_0 \right] * D = V_0 (0.5 - D)$$

So, the equation for output voltage is given by,

$$V_0 = 2 \left( \frac{N_s}{N_p} \right) * D * V_{dc}$$

### 3. Simulation in MATLAB/SIMULINK

In the fig 1, it shows the conventional full bridge converter with R load in open loop MATLAB software.

**Design parameters:**

Input voltage,  $V_{in} = 24 \text{ V}$

Input current,  $I_{in} = 4.16 \text{ A}$

Efficiency,  $\eta = 80\%$

Transformer Turns ratio,  $n = 2$

Inductance,  $L = 0.6 \text{ mH}$

Capacitance,  $C = 47 \mu\text{F}$  and resistance,  $R = 24 \Omega$

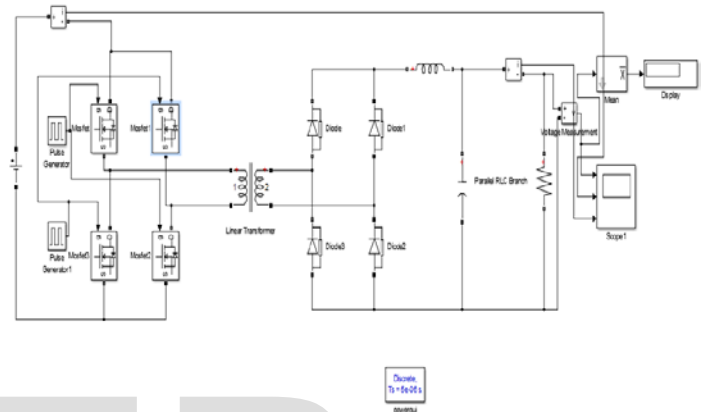


Fig. 1 SIMULATION OF FBC IN MATLAB/SIMULINK

### 4. Simulation Result

Results showing waveforms of output voltages (v) and current (A) with respect to time(in sec) with change in duty cycle

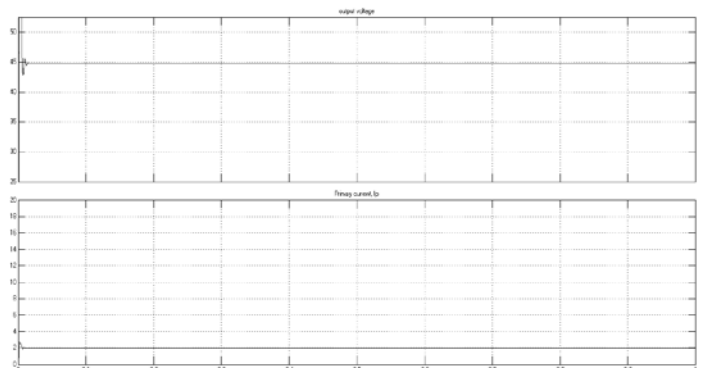


Fig.-2 :  $V_{IN} = 24$ , duty cycle=50%

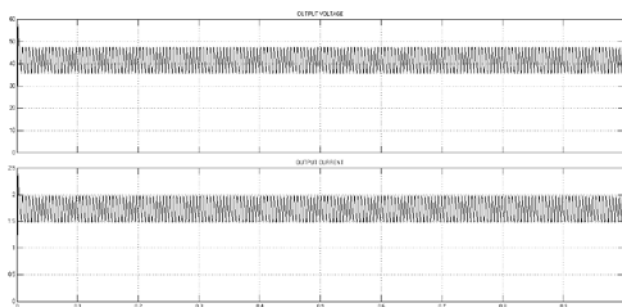


Fig-3 :  $V_{IN} = 24$ , Duty Cycle=40%



Figure 5:  $V_{IN} = 30$ , duty cycle=50%

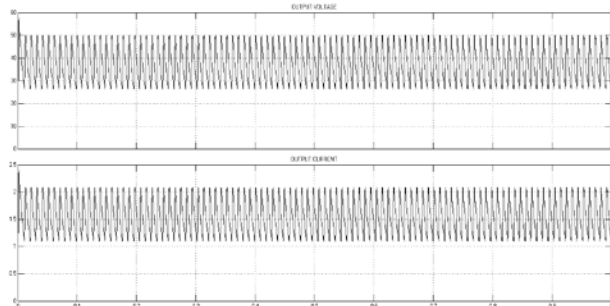


Fig-4 :  $V_{IN} = 24$ , Duty Cycle=30%

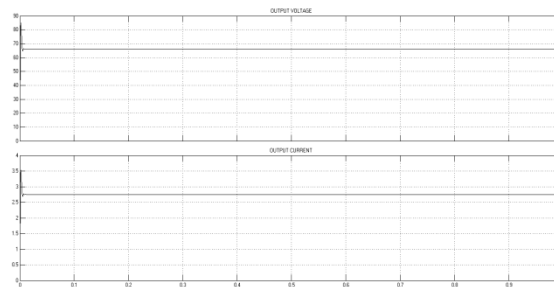


Figure 6:  $V_{IN} = 35$ , duty cycle=50%

The below table shows the values of actual output which is obtained from simulations and the values which are calculated with the help of equations are shown for different duty cycle with constant input voltage.

Input voltage	Duty cycle(%)	Voltage (V)			Current (A)		
		Calculated	Actual	Error	Calculated	Actual	Error
24 V	50	48	44.83	3.17	2.08	1.8	0.28
24V	40	38.4	41.74	-3.3	2.6	1.7	0.9
24V	30	28.8	27.62	1.18	3.4	1.15	2.3

Table-1:open loop response with change in duty cycle

From table above , it can be said that the value of output voltage depends on the duty cycle. As the value of duty cycle increases, the value of output voltage also increases. The change is proportion to each other.

**Results showing waveforms of output voltages (v) and current (A) with respect to time(in sec) with Change in input voltage**

The below table shows the values of actual output which is obtained from simulations and the values which are calculated with the help of equations are shown for different duty cycle with constant input voltage.

Input voltage	Duty cycle	Voltage (V)			Current (A)		
		Calculated	Actual	Error	Calculated	Actual	Error
24	50	48	44.83	3.2	2.08	1.9	0.1
30	50	60	56.42	3.5	1.6	2.35	-0.7
35	50	70	66.08	3.9	1.4	2.75	-1.3

Table-2:open loop response with change in input voltage

For different input voltage with constant duty cycle value of output voltages are different. As the value of input voltage increases, the value of output voltage also increases. Thus, output voltage depends on the value of input voltage.

From table 1 and 2, we conclude that the value of output voltage of full-bridge converter is dependent on the value of input voltage and also duty cycle.

## Simulation of close loop with R load using PI Controller

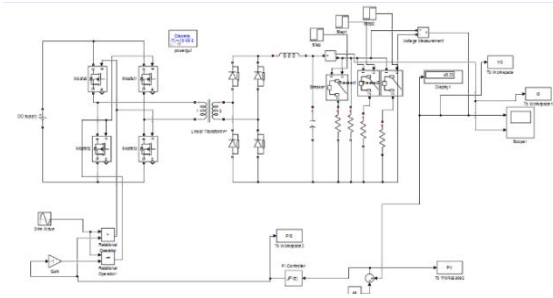


Figure 7: simulation of FBC with PI controller

### Design parameters:

Input voltage,  $V_{in} = 24$  V

Output Voltage,  $V_0 = 48$  V

Efficiency,  $\eta = 80\%$

Transformer Turns ratio,  $n = 2$

Inductance,  $L = 0.6$  mH

Capacitance,  $C = 47$   $\mu$ F and resistance,  $R = 24$   $\Omega$

### Transformer design:

Switching frequency = 20kHz

Primary voltage,  $V_1 = 24$  V

Secondary voltage,  $V_2 = 48$  V

Primary resistance,  $R_1 = 0.3801$  m $\Omega$

Secondary resistance,  $R_2 = 1.0743$  m $\Omega$

Primary inductance,  $L_1 = 1.376$  mH

Secondary inductance,  $L_2 = 10.99$  mH

Magnetization resistance,  $R_m = 5$   $\Omega$

Magnetization inductance,  $L_m = 45.83$  H

**Output Voltage Waveform of close loop with R load using PI Controller**

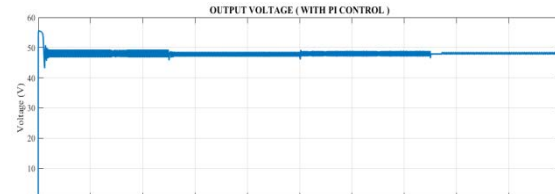


Figure-8 : FB output voltage with PI control

The PI controller output will be compared with the sine wave and the modulation will be done due to which pulses of cycle 0 and 1 is generated which is used in the switching on and off of the MOSFET switch.

**Output Current Waveform of close loop with R load using PI Controller**

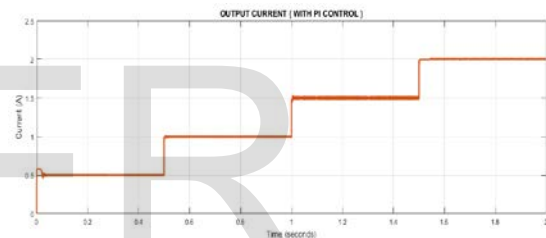


Figure-9: FB Output Current With PI Control

As shown in above figure 33, the output current is changing with change in load but output voltage remains constant in PI control.

## 5. Conclusion

Thus, in this paper, DC voltage regulation from one level to another level, from 24v to 48v, is derived using isolated Full-bridge dc-dc converter for unity feedback system. In close loop system, PI control strategy is used for voltage regulation.

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