

Analysis and Simulation of Full-Bridge Boost Converter using Matlab

O. Alavi, and S. Dolatabadi

Abstract—Improvement of high power and high performance applications causes attention to the DC-DC converter topologies. In this paper we analyze and simulate full-bridge boost converter, an isolated DC-DC converter. The advantages of isolated DC-DC converters include high efficiency, low manufacturing cost, safety, electrical isolation using transformer. The transformer is used to produce a higher voltage in secondary voltage side. Matlab Simulink is used for simulation of this converter. Nominal input voltage in this simulation is 30V and the output voltage is 55V. Also other parameters are given in this paper.

Index Terms—Full-bridge; isolated boost converter; duty cycle; converter topology

I. INTRODUCTION

NOWADAYS isolated DC-DC converters are very popular and used in different sections and applications. These converters have some advantages compared to the non-isolated converters, like high efficiency, low manufacturing cost, electrical isolation using transformer [1-3]. In many of the applications, we need to have isolation between input and output. Isolation can be done by simply connecting a transformer at the converter input. When we need a large step-up or step-down conversion ratio the transformer can improve the performance of the converter [2]. By choosing the appropriate ratio, the voltage or current stresses on the transistors and diodes can be reduced [1]. There are different topologies for the isolated converters. In this paper we will describe the isolated full-bridge boost converter topology. This topology is very useful in high power applications. Also A variety of circuit topologies can be used for the full-bridge boost converter. In this paper we analyze a topology in Fig.1. Isolated full bridge boost converters can be obtained by inversion of the source and load of isolated full bridge buck converters. The circuit performance of this converter in the first and second subinterval is equivalent to basic non-isolated boost converter. By placing the ratio of 1:1 for the transformer, output and induction current waveforms are the same waveforms for non-isolated boost converter.

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This paper outlines the design and analysis of a full-bridge boost converter with considering losses [1].

In the first stage of designing of the full bridge power converter, we estimate the required parameters according to the known data of the converter. In this simulation, in regular simulation method with respect to voltage input range (18-40 volt) and fixed voltage output (55 volt). We can do this simulation with the appropriate input voltage value (30 volt) for the converter. For this simulation we used Matlab Simulink and we will explain simulation steps in order in this paper.

TABLE I
CONVERTER SPECIFICATION

Voltage Input	18 – 40 v (nominal: 30 v)
Voltage Output	55 v
Load Power	10 – 150 w
$\Delta(i)$	2 %
$\Delta(v)$	3 %

For this converter, the high peak input voltage and wide input voltage range are items that will be challenging to meet. Since the converter has only one main control variable, duty-cycle, then in order to maintain a constant output voltage in the presence of a wide input voltage range, the duty-cycle will also have a wide operating range. However, it is important to keep in mind that the duty-cycle control range for practical reasons, should be in range of duty-cycle maximum and minimum [1,4].

II. CONVERTER TOPOLOGY

The various arrangements of the components, and their operation, will dictate the converter characteristics which give rise to many different topologies, such as buck, Fly-back and bridge converters. It is the strategic placing of the components that will expose them to certain electrical and thermal stress which translates to volume, weight and cost of the overall system. In an effort to minimize the key drivers of volume weight and cost, the designer is forced to find a balance between converter performance and customer satisfaction. Some selected topologies and their inherit capabilities are listed in Table II [5]:

TABLE II
DIFFERENT CONVERTER TOPOLOGIES

Topology	Power Range (W)	$V_{in}(dc)$ Range	In/Out Isolation	Typical Efficiency (%)	Relative Parts Cost
Buck	0-1000	5-1000	No	78	1.0
Boost	0-150	5-40	No	80	1.0
Buck-Boost	0-150	5-40	No	80	1.0
IT forward	0-150	5-500	Yes	78	1.4
Flyback	0-150	5-500	Yes	80	1.2
Push-Pull	100-1000	50-1000	Yes	75	2.0
Half-bridge	100-500	50-1000	Yes	75	2.2
Full-bridge	400-2000	50-1000	Yes	73	2.5

Justification of an isolation transformer for this design is given for two reasons, safety and step-down capability. Although the output voltage of 55V is in the “safe range”.

The input voltage is well beyond anything that you would want to come in contact with. Therefore, galvanic isolation provided by a transformer would be appreciated. Additionally, the transformer allows one to set a turns-ratio to assist with large difference between input and output voltages, as is the case in this design.

The electrical block diagram from the converter is given in Figure 1 [1]:

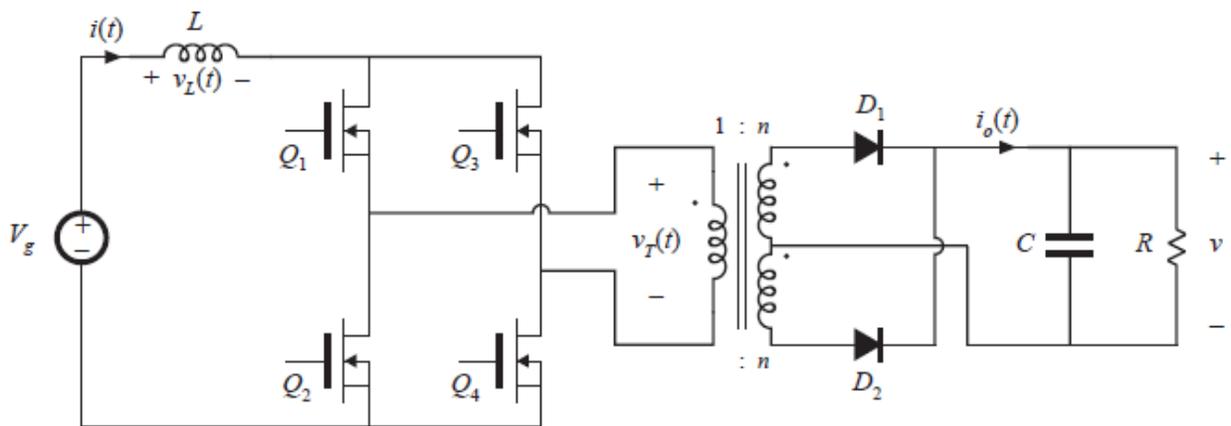


Fig. 1. The schematic of Full-bridge transformer-isolated boost converter

need to add an inductor parallel with transformer in primary side of transformer. The electrical block diagram from the converter with transformer equivalent circuit is given in Figure 2:

This schematic is for ideal mode. To consider the losses, we

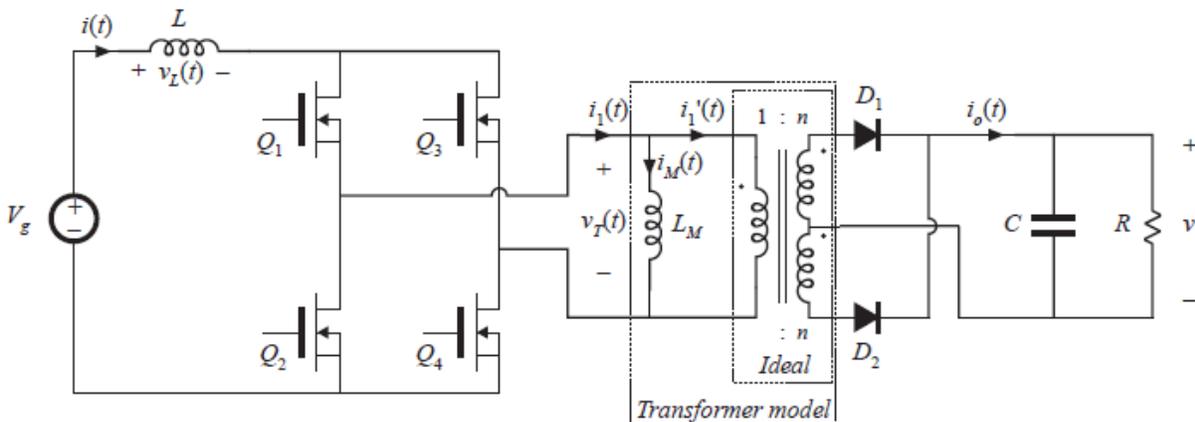


Fig. 2. The Full-bridge boost converter circuit with considering losses

To draw the waveforms we should analysis converter in conditions of operation.

III. CONVERTER ANALYSIS

One of the properties of full-bridge is extending the range of the function to 2TS. So transformer volt-second balance is obtained over two switching periods [1]. For full-bridge converter analysis we can remove Lm and default set Lm value in simulation software.

1-During first switching period: transistors Q1 and Q4 conduct for time DT_s, applying volt-seconds VDT_s to secondary winding.

2-During next switching period: transistors Q2 and Q3 conduct for time DT_s, applying volt-seconds -VDT_s to secondary winding.

Mode 1: 0 < t < DT_{s1}

In Mode 1, all of transistors are turned on. This operation causes two diodes to be reverse-biased. Operations are shown in below:

Q1	Q2	Q3	Q4	D1	D2
ON	ON	ON	ON	OFF	OFF

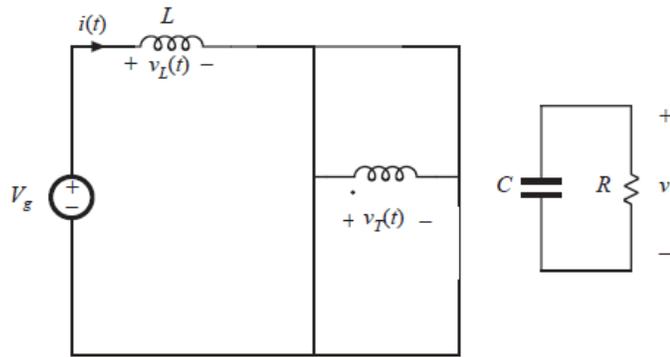


Fig. 3. The Full-bridge boost converter operation in Mode 1

$$v_L = v_g \tag{1}$$

$$v_T = 0 \tag{2}$$

$$i_c = -\frac{v}{R} \tag{3}$$

$$i_o = 0 \tag{4}$$

Mode 2: DT_{s1} < t < T_{s1}

In Mode 2, transistors Q2 and Q3 are turned off. Inductor L is connected with transistors Q1 and Q4 through the transformer and diode D1 to the dc output. Operations are shown in below:

Q1	Q2	Q3	Q4	D1	D2
ON	OFF	OFF	ON	ON	OFF

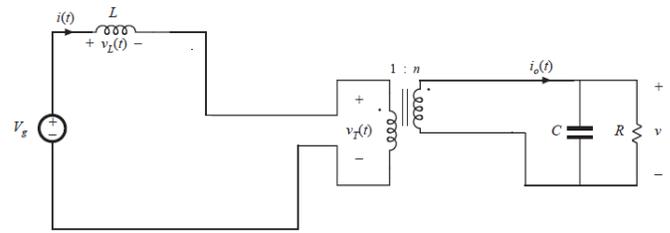


Fig. 4. The Full-bridge boost converter operation in Mode 2

$$v_L = v_g - v_T \tag{5}$$

$$v_T = \frac{v}{n} \tag{6}$$

$$i_c = i_o - \frac{v}{R} \tag{7}$$

$$i_o = i_c + \frac{v}{R} \tag{8}$$

$$i_o = \frac{i}{n} \tag{9}$$

Mode 3: 0 < t < DT_{s2}

In Mode 3, the operations is similar to Mode 1, all of transistors are turned on. This operation causes two diodes to be reverse-biased. Operations are shown in below:

Q1	Q2	Q3	Q4	D1	D2
ON	ON	ON	ON	OFF	OFF

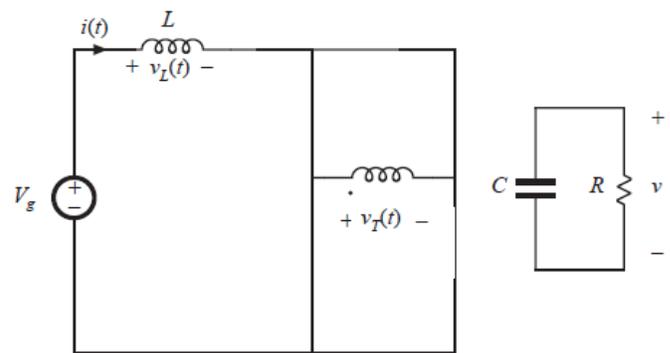


Fig. 5. The Full-bridge boost converter operation in Mode 3

$$v_L = v_g \tag{10}$$

$$v_T = 0 \tag{11}$$

$$i_c = -\frac{v}{R} \tag{12}$$

$$i_o = 0 \tag{13}$$

Mode 4: DT_{s2} < t < T_{s2}

In Mode 4, transistors Q1 and Q4 are turned off. Inductor L is connected with transistors Q2 and Q3 through the transformer and diode D2 to the dc output. Operations are shown in below:

Q1	Q2	Q3	Q4	D1	D2
OFF	ON	ON	OFF	OFF	ON

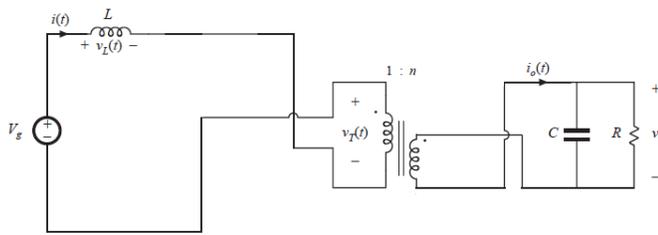


Fig. 6. The Full-bridge boost converter operation in Mode 4

$$v_L = v_g + v_T \tag{14}$$

$$v_T = -\frac{v}{n} \tag{15}$$

$$i_c = i_o - \frac{v}{R} \tag{16}$$

$$i_o = i_c + \frac{v}{R} \tag{17}$$

$$i_o = \frac{i}{n} \tag{18}$$

So we can draw waveforms for this converter. At first, application of ampere-second balance to capacitor current waveform:

$$\langle i_c \rangle = 0 = D \left(-\frac{v}{R} \right) + D' \left(i_o - \frac{v}{R} \right) \tag{19}$$

$$i_o = \frac{i}{n} \Rightarrow I = \frac{nv}{RD'} \tag{20}$$

Then we should calculate capacitor voltage and inductor current with these equations:

$$C \frac{dv_c}{dt} = i_c \Rightarrow \frac{dv_c}{dt} = \frac{i_c}{C} \tag{21}$$

$$L \frac{di_L}{dt} = v_L \Rightarrow \frac{di_L}{dt} = \frac{v_L}{L} \tag{22}$$

With these equations in Mode 1-4 we can draw waveforms. The waveforms diagram from the converter is given in Figure 7.

Application of volt-second balance to inductor voltage waveform:

$$\langle v_L \rangle = D(v_g) + D' \left(v_g - \frac{v}{n} \right) = 0 \tag{23}$$

With solving Equation 23, we can find M(D):

$$M(D) = \frac{v}{v_g} = \frac{n}{D'} \tag{24}$$

Equation 24 shows boost Conversion ratio M (D) with turns ratio n.

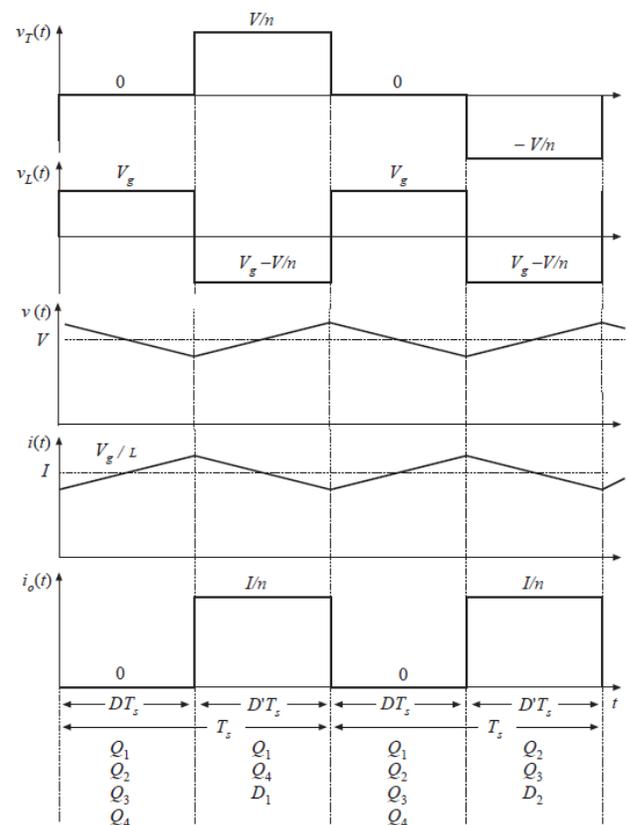


Fig. 7. The voltage and current waveforms of Full-bridge boost converter

IV. CONVERTER PARAMETERS ANALYSIS

A. Turns Ratio Selection

The turns ratio is determined by assuming that the nominal voltage for this converter is exactly in the middle of the input voltage range, 30V. Then the duty-cycle, being limited to 45% is chosen to be exactly in the range [1]. In this manor, the duty cycle can be adjusted higher or lower in equal quantities to accommodate the input voltage range of 18V to 40V. Since the output of our converter is 55V, and given the voltage transfer function derived in past equation, we can now select the appropriate turns-ratio as follows:

$$\frac{v}{v_g} (1 - D) = n \tag{25}$$

With this equation we can find n and correct D value, With 1:1 turns ratio, inductor current i(t) and output current io(t) waveforms are identical to non-isolated boost converter regularly maximum value of duty-cycle is 0.45, so primary duty-cycle is chosen to be exactly in the middle of its range or 22.5%, but in full-bridge maximum duty-cycle is (2×Dmax):

$$\frac{v}{v_g} (1 - D) = n \Rightarrow \frac{55}{30} (1 - 0.225) = n \Rightarrow n = 1.42$$

$$\frac{v}{v_g} (1 - D) = n \Rightarrow \frac{55}{30} (1 - (2 * 0.225)) = n \Rightarrow n = 1 \tag{26}$$

So we set n in range of 1-1.4: $n=1.2$
 Next step is checking of duty-cycle:

$$I = \frac{nv}{RD'} = 1.2 * \frac{55}{25+0.655} = 4 \tag{32}$$

$$v_g = 18 V \Rightarrow \frac{55}{18}(1 - D) = 1.2 \Rightarrow D = 0.6$$

$$L = \begin{cases} L_{min} = 388 \mu H \\ L_{max} = 863 \mu H \end{cases} \Rightarrow L_{nom} = 650 \mu H$$

$$v_g = 40 V \Rightarrow \frac{55}{40}(1 - D) = 1.2 \Rightarrow D = 0.13$$

The minimum value of the output capacitor can be determined from this equation [6]:

$$v_g = 30 V \text{ nom} \Rightarrow \frac{55}{30}(1 - D) = 1.2 \Rightarrow D = 0.345 \leq 0.45 \tag{27}$$

$$C > \frac{D}{Rf_s(\frac{\Delta v}{V})} \tag{33}$$

B. Select L, C and R:

In Converter Specification table (Table. I), we have Power of load in range of 10-150w, with Equation 28 we can find R range:

$$R = \frac{v^2}{P} \tag{28}$$

f_s is switching frequency, we can find capacitor value from this:

$$R_{min} = \frac{v^2}{P_{max}} = \frac{55^2}{150} = 20.17 \tag{29}$$

$$C > \frac{0.345}{25 * 10^5 * 0.03} \Rightarrow C > 4.6 \mu F$$

$$R_{max} = \frac{v^2}{P_{min}} = \frac{55^2}{10} = 302.5 \tag{30}$$

In this simulation we used $C=25 \mu F$.

From waveforms diagram we can find L value:

$$L = \frac{v_g DT_s}{2\Delta i} \Rightarrow L = v_g * 0.345 * \frac{10^{-5}}{2*0.02*1} \tag{31}$$

V. SIMULATION VALIDATION

The models derived in the previous sections were simulated using Simulink; the circuit diagram is shown in Figure 8:

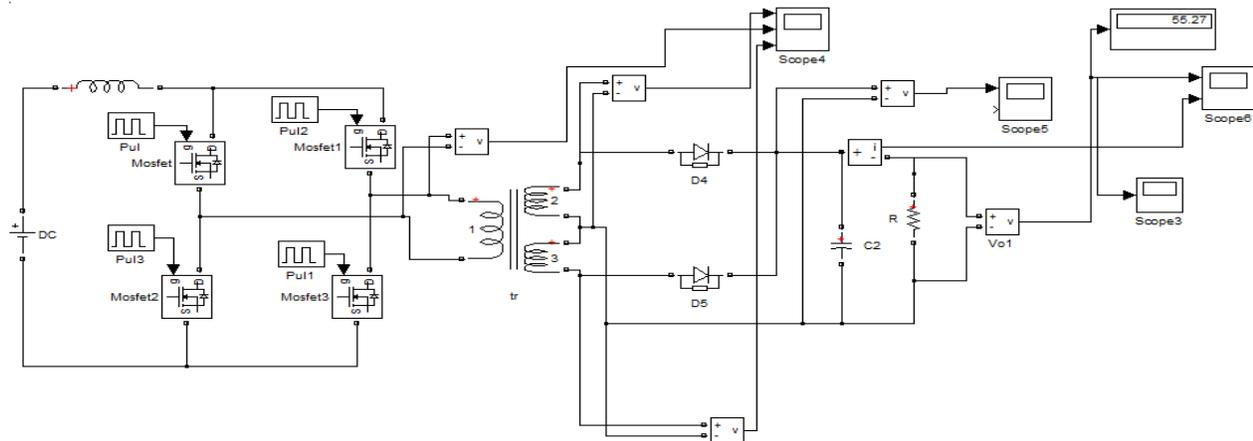


Fig. 8. Matlab simulation scheme construction of Full-bridge boost converter

For setting of pulse generators we can find suitable duty-cycle with this method:

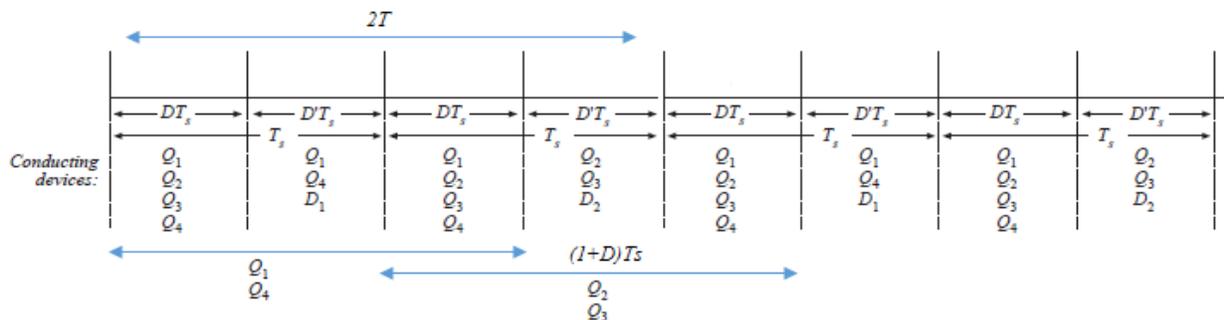


Fig. 9. The determination of Full-bridge boost converter duty-cycle

We set $2T_s$ for pulse generator period and $(1 + \frac{D}{2}) \times 100\%$ for pulse width. For Q1 and Q4 we set phase delay to 0, for Q2 and Q3 we set phase delay to T_s . For considering losses we set L_m , R_m to transformer configurations.

The simulated results are provided in Figure10.

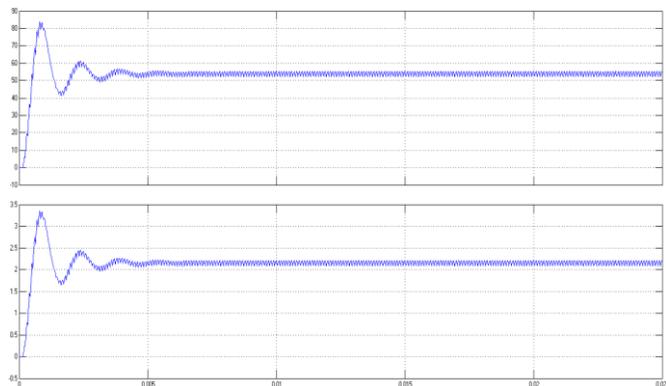


Fig. 10. The Full-bridge boost converter output voltage and current waveforms

Zoom in on the output voltage and current ripple:

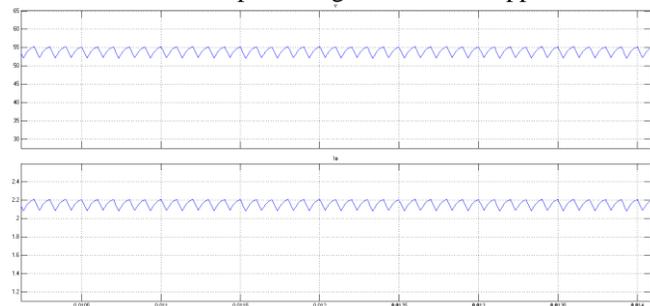


Fig. 11. Zoom in on the Full-bridge boost converter output voltage and current

Primary and secondary sides of transformer voltages in simulation:

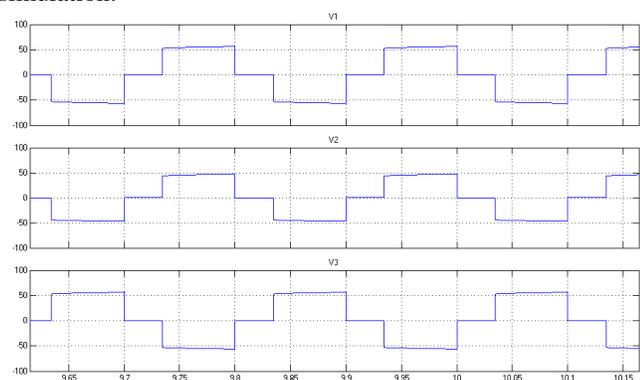


Fig. 12. The voltage waveforms of transformer

VI. CONCLUSION

Full-Bridge boost converter is simulated using Matlab Simulink. Voltage and current waveforms are similar to waveforms of the transformer-isolated full-bridge boost converter in CCM operation. With given converter

specification, we calculated simulation parameters, and with setting of great duty-cycle and turns ratio we could to reach the CCM waveforms. Calculating duty-cycle in this paper is 0.345 and turns ratio constant is 1.2.

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BIOGRAPHIES



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