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International
Journal
Of Modern Engineering Research (IJMER)

Transformer less Boost Converter Topologies with Improved Voltage Gain Operating In Continuous Conduction Mode

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ABSTRACT: *In this project, a new step up converter proposed in a recent work is analyzed, designed, simulated with MATLAB Simulink. Conventional dc–dc boost converters are unable to provide high step-up voltage gains due to the effect of power switches, rectifier diodes, and the equivalent series resistance of inductors and capacitors. This paper proposes transformer less dc–dc converters to achieve high step-up voltage gain without an extremely high duty ratio. In the proposed converters, two inductors with the same level of inductance are charged in parallel during the switch-on period and are discharged in series during the switch-off period. The structures of the proposed converters are very simple.*

Keywords: *DC-DC boost converter, high step up voltage gain, DC–DC boost converter, high step-up voltage gain.*

I. Introduction

Power electronics is:" The technology associated with the efficient conversion, control and conditioning of electric power by static means from its available input form into the desired electrical output form." The goal of power electronics is to realize power conversion from an electrical source to an electrical load in a highly efficient, highly reliable and cost-effective way.

The application of power electronics includes a variety of fields such as energy storage, transmission and distribution, pollution avoidance, communication, computer systems, propulsion and transportation .Power electronics modules are key units in power electronics system. As the integration of power switches, device gating, sensors, controls and actuators, power modules can be used to perform energy transfer, storage and conditioning. According to the type of the input and output power, power conversion systems can be classified into four main categories, namely:

- AC to DC (rectification)
- DC to AC (inversion)
- AC to AC(cycloconversion)
- DC to DC(chopping)

A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage which is-typically- at a different voltage level than the input. Apart from voltage level conversion, DC-to-DC converters are used to provide noise isolation, power bus regulation. The typical usage of DC-DC converters is to convert unregulated dc voltage to regulated or variable dc voltage at the output. The output voltage in DC-DC converters is generally controlled using a switching concept. In fact, early DC-DC converters were known as choppers with silicon-controlled rectifiers (SCRs) used as the switching mechanism.

Modern DC-DC converters employ insulated gate bipolar transistors (IGBTs) and metal oxide silicon field effect transistors (MOSFETs) as they possess attractive switching capabilities, especially in terms of switching frequency and power ratings. Based on their performances, DC-DC converters are subcategorized into three general types; Buck Converters which convert from a voltage level to a relatively lower voltage level. Conversely, Boost Converters transform to higher voltage level. The third one is buck-boost converter which can either be a buck or a boost converter based on its control signals.

A DC–DC converter with a high step-up voltage gain is used for many applications, such as high-intensity discharge lamp ballasts for automobile headlamps, fuel-cell energy conversion systems, solar-cell energy conversion systems, and battery backup systems for uninterruptible power supplies. Theoretically, a dc–dc boost converter can achieve a high step up voltage gain with an extremely high duty ratio. However, in practice, the step-up voltage gain is limited due to the effect of power switches, rectifier diodes, and the equivalent series resistance (ESR) of inductors and capacitors. Moreover, the extremely high duty-ratio operation will result in a serious reverse-recovery problem. Many topologies have been presented to provide a high step-up voltage gain without an extremely high duty ratio.

A dc–dc flyback converter is a very simple structure with a high step-up voltage gain and an electrical isolation, but the active switch of this converter will suffer a high voltage stress due to the leakage inductance of the transformer. For recycling the energy of the leakage inductance and minimizing the voltage stress on the active switch, some energy-regeneration techniques have been proposed to clamp the voltage stress on the active switch and to recycle the leakage-inductance energy.

For recycling the energy of the leakage inductance and minimizing the voltage stress on the active switch, some energy-regeneration techniques have been proposed toclamp the voltage stress on the active switch and to recycle the leakage-inductance energy. The coupled-inductor techniques provide solutions to achieve a high voltage gain, a low voltage stress on the active switch, and a high efficiency without the penalty of high duty ratio

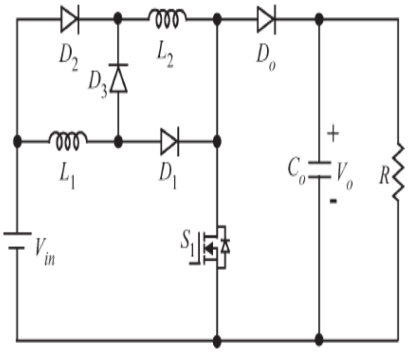


Figure. 1. Transformerless dc–dc high step-up converter.

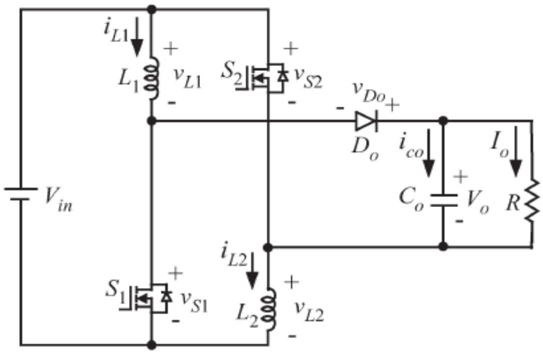
The modified boost type with switched-inductor technique is shown in Fig. 1 The structure of this converter is very simple. Only one power stage is used in this converter. However, this converter has two issues:

1). Three power devices exist in the current-flow path during the switch-on period, and two power devices exist in the currentflow path during the switch-off period, and
2). The voltage stress on the active switch is equal to the output voltage.

II. Proposed Converters

Figure 2 shows the three proposed topologies. These three proposed dc–dc converters utilize the switched inductor technique, in which two inductors with same level of inductance are charged in parallel during the switch-on period and are discharged in series during the switch-off period, to achieve high step-up voltage gain without the extremely high duty ratio. The operating principles and steady-state analysis are discussed in the following sections. To analyze the steadystate characteristics of the proposed converters, some conditions are assumed as follows:

1) All components are ideal—the ON-state resistance *R*DS(ON) of the active switches, the forward voltage drop of the diodes, and the ESRs of the inductors and capacitors are ignored
2) all capacitors are sufficiently large, and the voltages across the capacitors can be treated as Constant



(a)

Figure 2(a) proposed converter 1

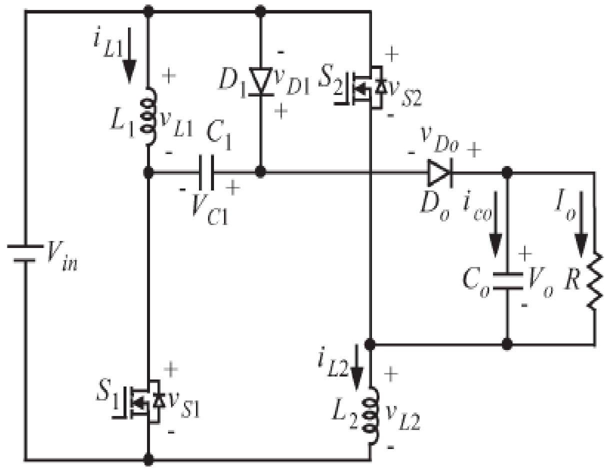


Figure 2(b) proposed converter 2

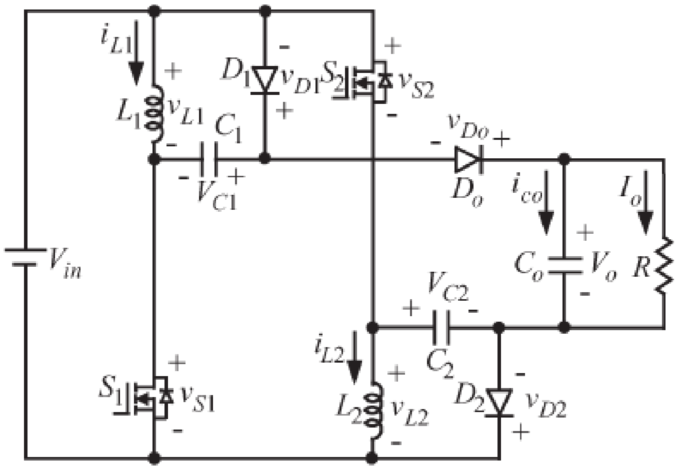


Figure 2(c) proposed converter 3

2.1 PROPOSED CONVERTER 1

Figure 2(a) shows the circuit configuration of the proposed converter I, which consists of two active switches (*S*1 and *S*2), two inductors (*L*1 and *L*2) that have the same level of inductance, one output diode *Do*, and one output capacitor *Co*. Switches *S*1 and *S*2 are controlled simultaneously by using one control signal. Figure 3 shows some typical waveforms obtained during continuous conduction mode (CCM)

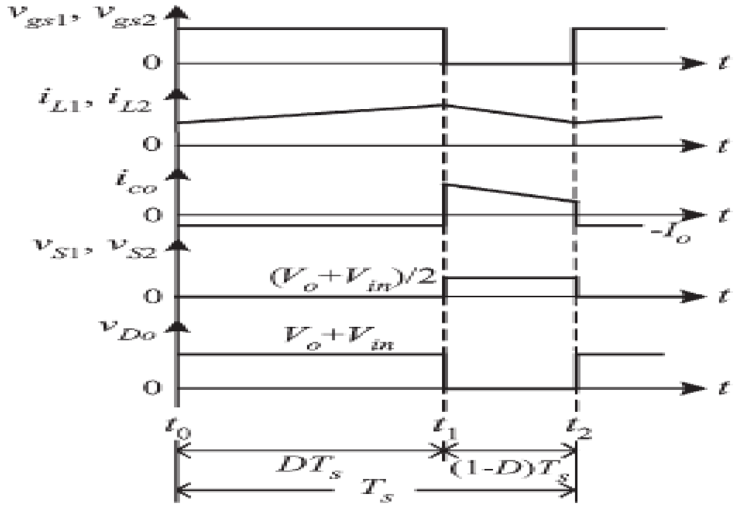


Figure 3 waveforms of converter 1

2.1 A. CCM Operation

The operating modes can be divided into two modes, defined as modes 1 and 2. Figure 3 Some typical waveforms for the proposed converter I.CCM operation.

1) Mode 1 [$t0$, $t1$]. During this time interval, switches $S1$ and $S2$ are turned on. The equivalent circuit is shown in Fig. 4(a). Inductors $L1$ and $L2$ are charged in parallel from the dc source, and the energy stored in the output capacitor Co is released to the load. Thus, the voltages across $L1$ and $L2$ are given as

$$vL1 = vL2 = Vin \quad \text{(3.1.1)}$$

2) Mode 2 [$t1$, $t2$]. During this time interval, $S1$ and $S2$ are turned off. The equivalent circuit is shown in Figure. 4(b). The dc source, $L1$, and $L2$ are series connected to transfer the energies to Co and the load. Thus, the voltages across $L1$ and $L2$ are derived as

$$vL1 = vL2 = Vin - Vo/2 \quad \text{(3.1.2)}$$

By using the volt–second balance principle on $L1$ and $L2$, the following equation can be obtained:

$$\int_0^{DTs} Vin\ dt + \int_{DTs}^{Ts} \frac{Vin - Vo}{2}\ dt = 0 \quad \text{(3.1.3)}$$

By simplifying (3), the voltage gain is given by

$$\frac{Vo}{Vin} = \frac{1+D}{1-D} \quad \text{(3.1.4)}$$

Voltage across s1 and s2 and diode is given by:

$$Vs1 = Vs2 = VD1 = \frac{V0}{2} \quad \text{(3.1.5)}$$

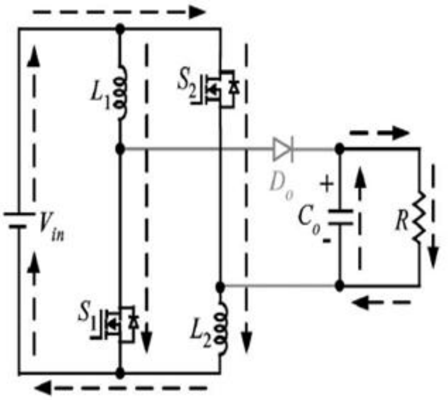


Figure 4(a); mode 1

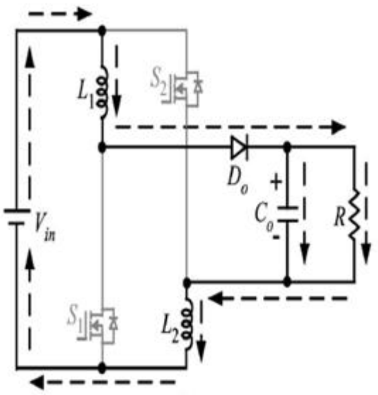


Figure 4(b): mode 2

2.2 PROPOSED CONVERTER 2

Figure 2(b) shows the circuit configuration of the proposed converter II, which is the proposed converter I with one voltage-lift circuit.Thus, two inductors ($L1$ and $L2$) with the same level of inductance are also adopted in this converter. Switches $S1$ and $S2$ are controlled simultaneously by one control signal.

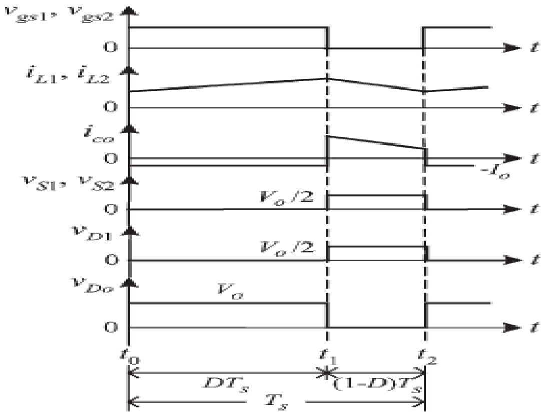


Figure 5 typical waveforms of proposed converter operating in CCM

2.2 A. CCM Operation

The operating modes can be divided into two modes, defined as modes 1 and 2.

1) **Mode 1 [*t*0, *t*1].**
   During this time interval, *S*1 and *S*2 are turned on. The equivalent circuit is shown in Fig. 6(a). *L*1 and *L*2 are charged in parallel from the dc source, and the energy stored in *Co* is released to the load. Moreover, capacitor *C*1 is charged from the dc source. Thus, the voltages across *L*1, *L*2, and *C*1 are given as

   $$vL1 = vL2 = VC1 = Vin.$$

2) **Mode 2 [*t*1, *t*2].**
   During this time interval, *S*1 and *S*2 are turned off. The equivalent circuit is shown in Fig.6(b). The dc source, *L*1, *C*1, and *L*2 are series connected to transfer the energies to *Co* and the load. Thus, the voltages across *L*1 and *L*2 are derived as

$$VL1 = VL2 = \frac{Vin+Vc1-V0}{2} = \frac{2Vin-Vo}{2} \text{…………………………..……………..(3.2.6)}$$

By using the volt–second balance principle on *L*1 and *L*2, the following can be obtained:

$$\int_0^{DTs} Vin\,dt + \int_{DTs}^{Ts} \frac{2Vin-V0}{2}\,dt = 0 \text{ …………………………………………………(3.2.7)}$$

So the voltage gain is given by

$$\frac{V0}{Vin} = \frac{2}{1-D} \text{……………………………………………………(3.2.8)}$$

The voltage stress on switches and diodes is given by:

$$\left.\begin{array}{l} VS1 = VS2 = VD1 = \frac{Vo}{2} \\ VDo = Vo \end{array}\right\} \text{…………………… (3.2.9)}$$

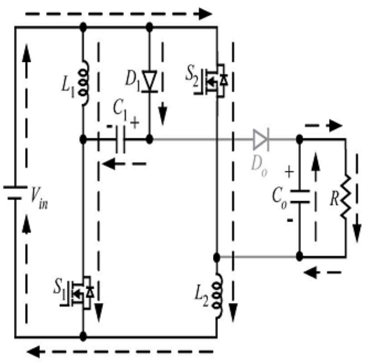


Figure 6(a): mode1

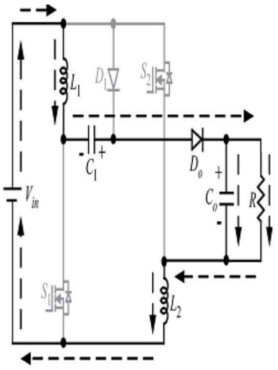


Figure 6(b): mode 2

2.3 PROPOSED CONVERTER 3

Figure. 2(c) shows the circuit configuration of the proposed converter III, which is the proposed converter I with two voltage lift circuits. Thus, two inductors (*L*1 and *L*2) with the same level of inductance are also adopted in this converter. Switches *S*1 and *S*2 are controlled simultaneously by one control signal.

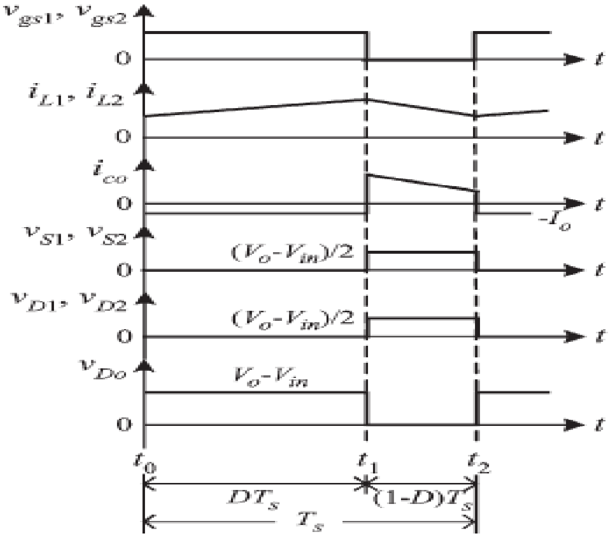


Figure 7: typical wave forms of proposed converter3 operating in CCM

2.3 A. CCM Operation

The operating modes can be divided into two modes, defined as modes 1 and 2.

1) **Mode 1 [*t*0, *t*1].**
During this time interval, *S*1 and *S*2 are turned on. The equivalent circuit is shown in Fig. 8(a). *L*1 and *L*2 are charged in parallel from the dc source, and the energy stored in *Co* is released to the load.

Moreover, capacitors *C*1 and *C*2 are charged from the dc source. Thus, the voltages across *L*1, *L*2, *C*1, and *C*2 are given as

$$vL1 = vL2 = VC1 = VC2 = Vin \ldots\ldots(3.3.10)$$

2) **Mode 2 [*t*1, *t*2].**
During this time interval, *S*1 and *S*2 are turned off. The equivalent circuit is shown in Fig. 8(b). The dc source, *L*1, *C*1, *C*2, and *L*2 are series connected to transfer the energies to *Co* and the load. Thus, the voltages across *L*1 and *L*2 are derived as

$$VL1=VL2=\frac{Vin+Vc1+Vc2-Vo}{2}=\frac{3Vin-Vo}{2}\ldots\ldots(3.3.11)$$

By using the volt–second balance principle on *L*1 and *L*2, the following can be obtained:

$$\int_0^{DTs} Vin\,dt+\int_{DTs}^{Ts}\frac{3Vin-V0}{2}=0\ldots\ldots(3.3.12)$$

Voltage gain of the circuit is given by

$$\frac{Vo}{Vin}=\frac{3-D}{1-D}\ldots\ldots(3.3.13)$$

Voltage stress across switches and diodes is given by:

$$\left.\begin{array}{l} VS1=VS2=VD1=VD2=\dfrac{Vo-Vin}{2} \\ VD0 = V0 - Vin \end{array}\right\}\ldots\ldots(3.3.14)$$

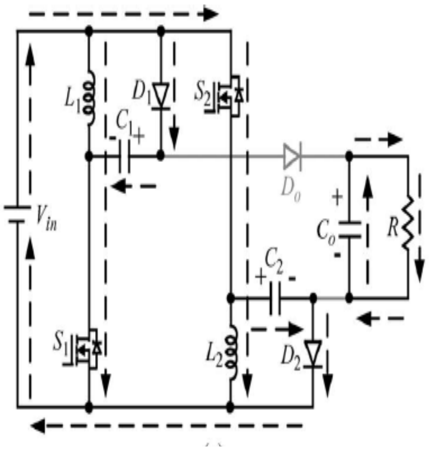


Figure 8(a): mode 1

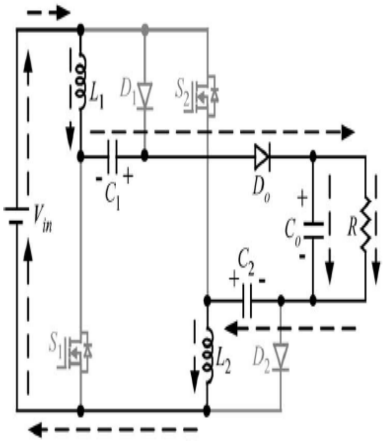


Figure 8(b):mode 2

III. Comparison of Proposed Converter and Boost Converter

The voltage stresses on the active switch and the voltage gains of the boost converter and the proposed converters are summarized in Table 4.1. The voltage stresses on the active switch of the three proposed converters are less than the voltage stress on the active switch of the boost converter, and thus, the active switches with low voltage ratings can be selected. Moreover, the curves of the voltage gain of the boost converter and the proposed converters

Table4.1: Comparison of Voltage Gain and Voltage Stress on Active Switch for Boost Converter and Three Proposed Converters

	GAIN	VOLTAGE STRESS
Boost converter	$\frac{1}{1-D}$	V0
Proposed converter 1	$\frac{1+D}{1-D}$	$\frac{V0+Vin}{2}$
Proposed converter 2	$\frac{2}{1-D}$	$\frac{V0}{2}$
Proposed converter 3	$\frac{3-D}{1-D}$	$\frac{V0-Vin}{2}$

IV. Simulation Results

This section carry simulation result of the improved topology by using MATLAB Simulink the parameter values that are used are

- L1= L2=100µH
- Fs(switching frequency)=100kHZ
- Co=33µF
- C1=C2=47µF
- Ro=250
- VO/Vin = (1+D)/(1-D) = 100/12

  . ’ . D= 78.57%

4.1 PROPOSED CONVERTER1

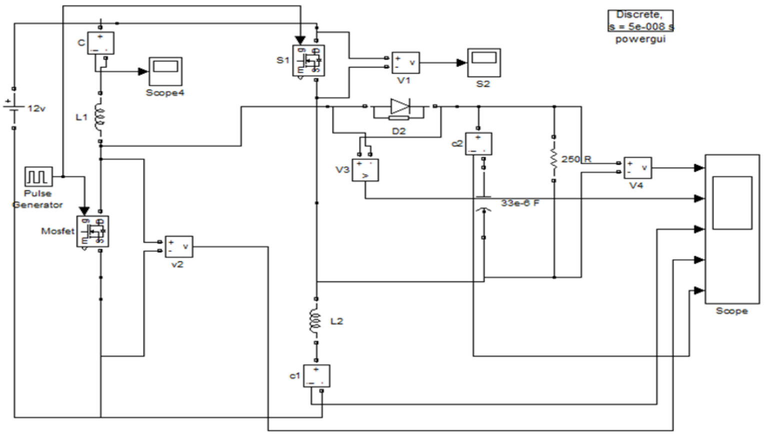


Figure 4.1.1 Simulation block diagram

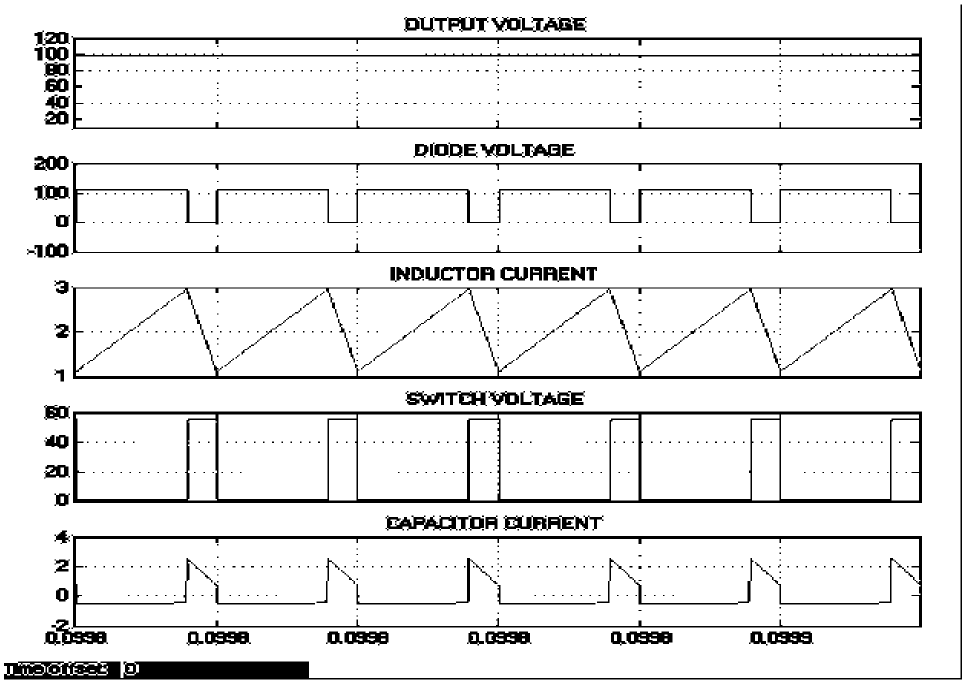


Figure 4.1.2 Output waveforms

4.2. PROPOSED CONVERTER 2

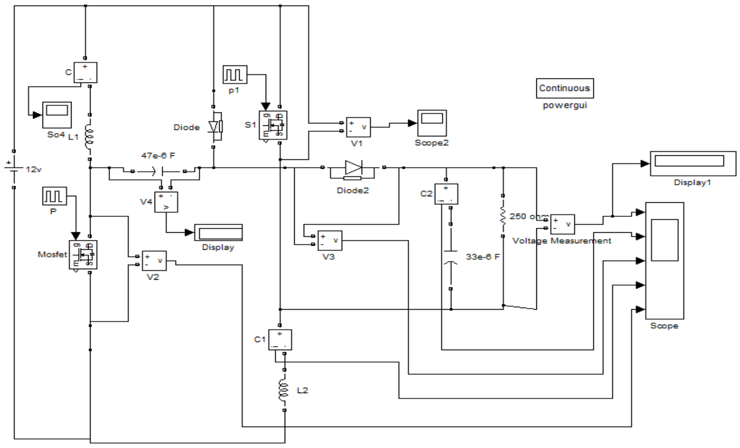


Figure 5.2.1: simulation block diagram

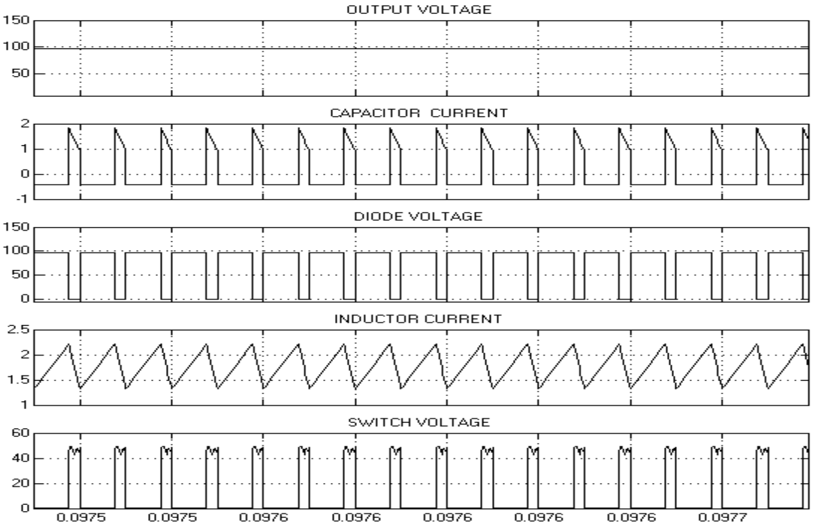


Figure 4.2.2 output waveforms

4.3 PROPOSED CONVERTER 3

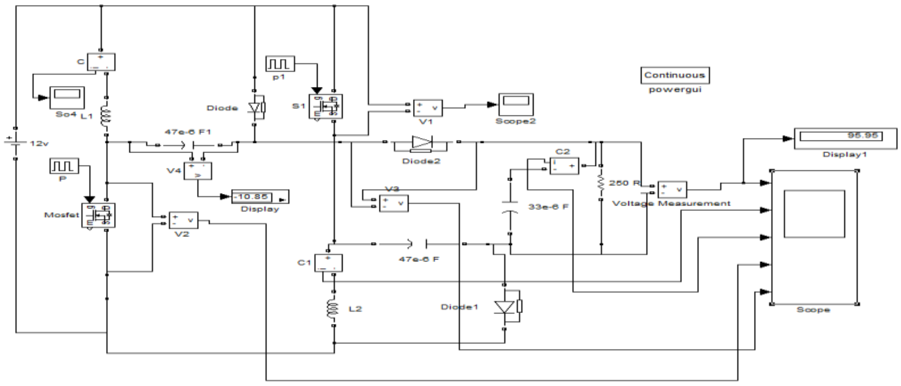


Figure 4.3.1: simulation block diagram

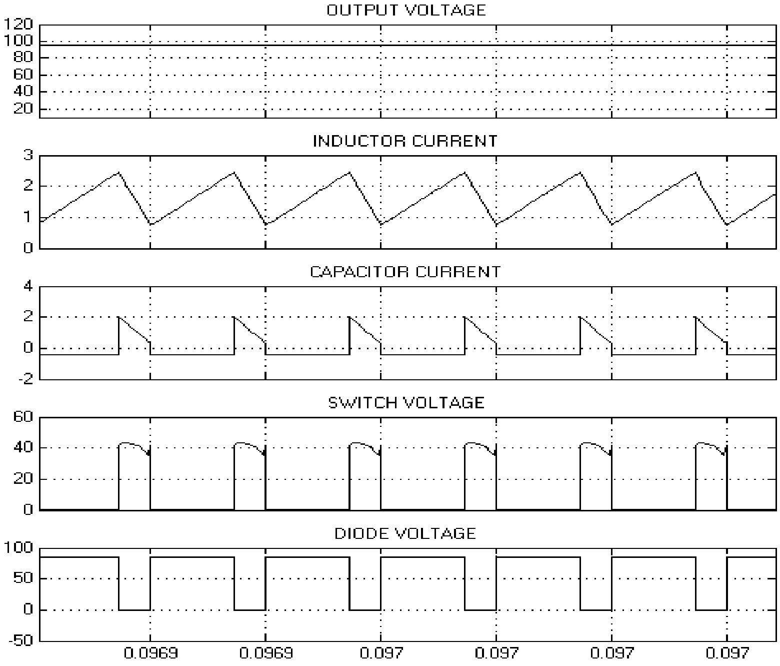


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Figure 4.3.2:0utput waveforms

4.4 BASIC CONVERTER

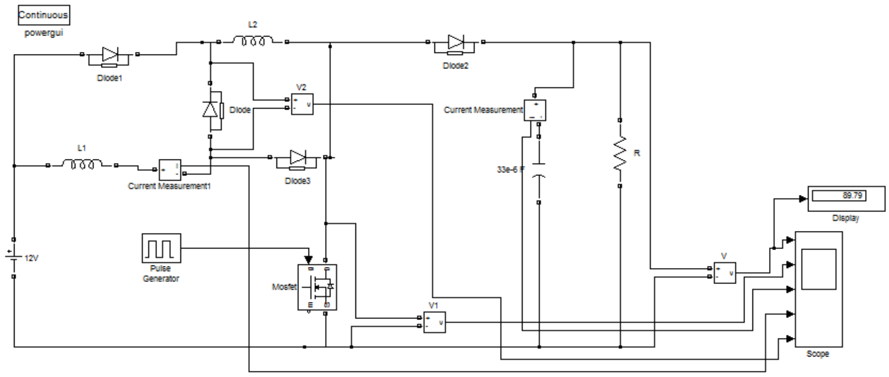

Figure 4.4.1: simulation block diagram

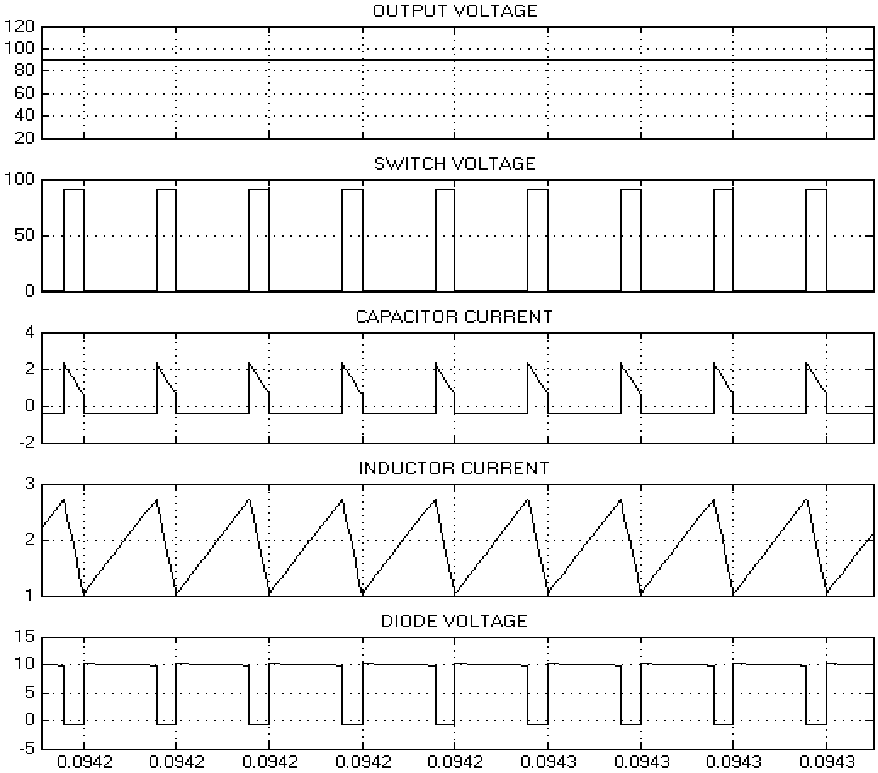

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Figure 4.4.2: output waveforms

V. Conclusion

DC-DC converters employ insulated gate bipolar transistors (IGBTs) and metal oxide silicon field effect transistors (MOSFETs) as they possess attractive switching capabilities, especially in terms of switching frequency and power ratings. DC- DC switching converters are becoming popular in industrial area and these converters suitable for applications where the output DC voltage needs to be larger than the DC input and can offer technical advantages economic.

This project has studied three Transformerless topologies with simple structures to reduce the power losses by decrease the switch voltage stress. The structures of the proposed converters are very simple. Since the voltage stresses on the active switches are low.

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