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Study and Analysis of PWM with DC-DC Converter for Inverting Buck-Boost Inverter Topology

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ABSTRACT

The simulation aims to study and analyze the effect of the duty cycle on the output voltage and signal reflection. This type of simulation is important for many practical applications of inverter boost converters, such as renewable energy systems or portable electronics. A voltage converter is being developed to generate a negative voltage output, i.e., it has the ability to invert the output signal. The converter's input is connected to a DC voltage source, and is intended to generate a higher or lower voltage, depending on the application requirements, while maintaining the inverting output signal. This converter is used in many fields, most notably those powered by batteries, such as portable devices, where the required voltage varies depending on the load. Converters regulate and provide a stable and suitable voltage for the batteries. A study and analysis of these converters will address these challenges by building and designing a simulation model to generate a voltage suitable for covering the load or charging the batteries, operating efficiently and reliably under various operating conditions. Its effectiveness can be verified through proposed tests covering operating conditions suitable for real-time operation. The first contribution is to verify the possibility of changing the converter output signal to the same value as the converter output voltage during the pulse generator duty cycle (50%). The second contribution is to verify the possibility of increasing the value of the converter output voltage in the pulse generator duty cycle (70%) or decreasing the value of the converter output voltage in the pulse generator duty cycle (20%). The results demonstrated the effectiveness of the proposed model and the possibility of changing the output voltage value with changing the output signal.

1. Introduction

Converters are used in many fields that require changing the type or quantity of electrical power due to varying power sources, including alternating current (AC) and direct current (DC) power sources [1]-[3]. Loads may also vary from the available power source, requiring appropriate power supply. The need to build and design Converters that help cover the required loads requires significant effort. Among the converters used are electronic power converters. Converters convert electrical quantities from a constant to a variable quantity, and from direct current to alternating current (DC) and vice versa [4]-[6]. They are of various types. The first type increases the electrical quantity without changing the power supply type, and includes an AC-to-AC electronic power converter with a fixed input voltage and frequency and a variable output. The second type is a DC-to-DC converter with a fixed input and a variable output depending on the amount required to cover the load. Another type, called a rectifier, changes the current type from AC to DC. A fourth type, called an inverter, converts DC voltage to AC voltage [7]-[10].

Electronic power converters are of a constant-value DC type that is converted to variable-value DC with a state of change in the output signal by an inverter, called an inverter, and it can also be the same value or greater or less depending on the pulse width modification in which the opening and closing of electronic switches is controlled [11]-[14]. There are two types of DC to DC converters: inverting and non-inverting. Inverting buck-boost inverter, the voltage signal is reversed, and the converter can operate with the same input and output value, i.e. with the aim of inverting the voltage signal, while there are two other cases, which are conversion with the two states of raising the voltage, called step-up, or lowering the voltage, called step-down, the output of the converter is less than the input value, so it is called Inverting buck-boost inverter [15]-[17]. The converter is called non-inverting because the output is positive and the input is positive, while it is called inverting because the output signal changes from the input signal and is the opposite of the signal, i.e. positive input and negative output [18]-[20].

Non-Inverting buck-boost inverter and Inverting buck-boost inverter, In the current study, the researchers present a simulation model based on a mathematical representation of electronic power converters. By conducting tests, the system's behavior can be identified under different operating conditions and dynamic analysis. Electronic power converters come in three forms: step-up, step-down, and step-down. Simulation can help us understand the behavior of the converter, as well as dynamic analysis and response. There are two concepts for the terms mentioned in the paragraph title. The first represents the output signal being the same as the input signal, which is called a non-inverting converter. The second concept is that the output signal is the opposite of the input signal, which is called an inverter. The other concept is that the converter produces an output with the same value as the input while maintaining the signal inversion property, or it can be a step-down or step-up converter while maintaining the signal inversion property [21]-[24].

Inverter buck-boost converters have the ability to step down or step up voltage. The converter consists of a diode, a transistor, a coil, a capacitor, a power source, and a load. The converter operates using electronic switches, and conversion depends on the on-off periods of the electronic switches and the charging and discharging of the capacitor, influenced by the coil current [25]-[28]. The capacitor also handles load fluctuations by providing stability and limiting voltage fluctuations. Electronic power converters work to provide a different quantity in the converter output than the input quantity. Inverting buck-boost inverter This type is one of the DC to DC converters, the output signal inverter type. It was proposed to conduct tests for a model designed to raise or lower the voltage quantity in the converter output than the quantity applied to the converter input. A model was developed consisting of two types of semiconductors that included an electronic switch, type IGBT transistor, in addition to a diode. The transistor is ignited by a pulse generator with a duty cycle (50%, 20%, and 70%) that can control the switch's opening and closing periods. The pulses were used to conduct three test cases that were proposed to obtain the same voltage with a change in the output signal as a first case at a duty cycle with a duty cycle (50%).

2. Method

Power Electronics Inverting Buck Boost Converter, the power electronic converter includes, boost, buck and buck boost. Also the buck-boost converter, power converters of this type are divided into two types: the first is the non-inverter buck-boost converter type and the second is the inverter buck-boost converter type. The inverter buck-boost converter differs in that it has the property of inverting the output signal, while the non-inverter buck-boost converter type has the same output signal as the input. The components of each type, the working characteristics of all the transformer parts, and how the output is obtained can be identified by tracing the circuit branch currents for the opening and closing of the electronic switches, the operation and disconnection of the diode, the charging and discharging of the capacitor, and the coil state through the change in the inductor voltage and current during the switching states of the electronic switches [29]-[32].

The components of the converter circuit can be viewed when two transistor switches in one configuration are used, as in Fig. 1. The first mode is when the first switch is closed and the second switch is open, and the first part represents the converter's action as a step-down switch, while the second part represents the converter's action as a step-up switch when the switches switch from open to closed for the second switch and from closed to open for the first switch [33]-[35].

In Fig. 2 show the general diagram of inverting buck boost converter that some time is called flyback converter. The components of a transformer can be described as consisting of one switch connected in series with the input terminal, i.e. the power source, and connected on the other side to a current branch point. The first is downward, through which the inductor current passes, and the second is a diode with reverse bias. Depending on the connection method, this part has two operating states: when the switch is closed, one behavior occurs, while another behavior occurs when the switch is open.

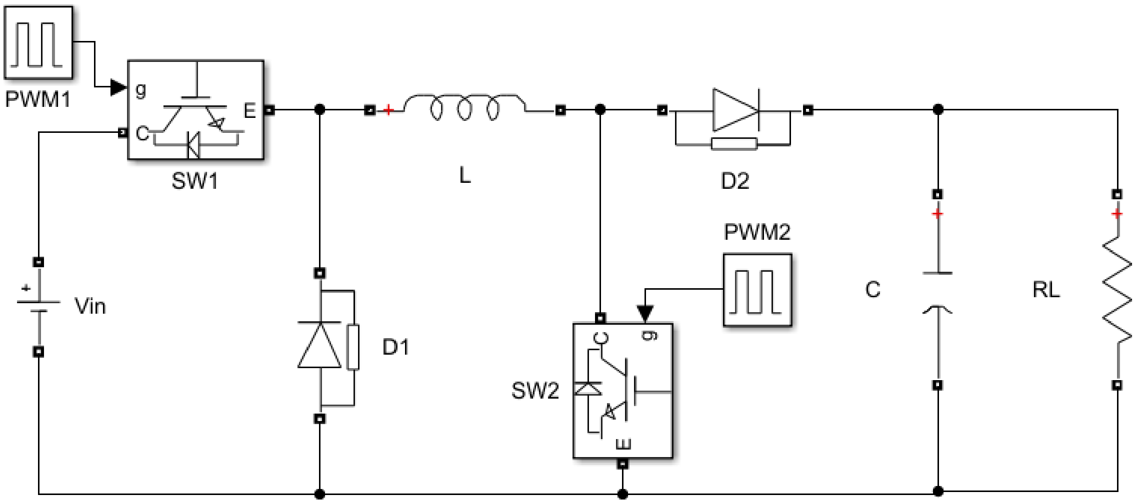

Fig. 1. Diagram of inverting buck boost converter with two transistor switches in one configuration

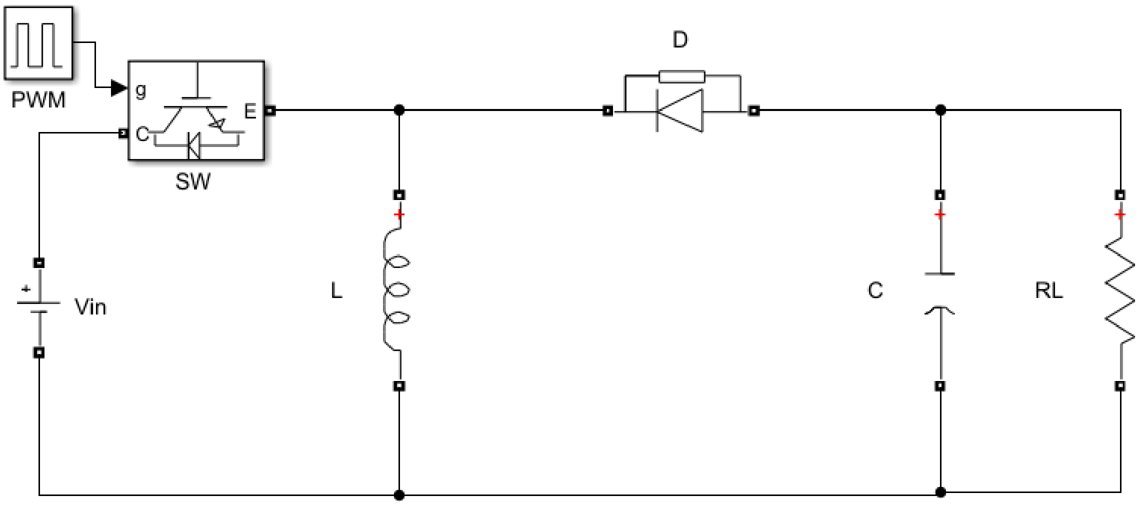

Fig. 2. Diagram of general inverting buck boost converter

The current passes through the inductor and does not pass through the diode when the switch is closed, while the current passes through the diode when the switch is open, which is the current produced by the inductor, which gradually decreases. The load is also connected to a capacitor in

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parallel, in addition to being connected to the same diode on the anode side. This is the path for completing the passage of the current resulting from the inductor when the switch is open. It is noted that the direction of the voltage is opposite to the direction of the current, which gives a negative signal to the value of the output voltage [36]-[40]. The switch's operating cycle periods are repeated, where the first cycle can be described by the time TS, while the second cycle is 2TS, and so on. In the first period, the switch changes state from on to off, called delta TS, and is divided into two period switch are Toff and Ton. In the first state, the switch is closed and the output is zero volts, due to the current not flowing through the diode, as it is reverse biased, which prevents the current from flowing through it. Thus, the source current passes through the inductor, and the source voltage is almost equal to the inductor voltage. While in the second period, when the switch changes state from on to off, the inductor passes current through the capacitor and the resistive load branches, as well as through the diode, since it allows current to flow in reverse bias. Thus, the output voltage can be almost the same as the input voltage, while the signal is negative due to the current flowing opposite the polarity of the output voltage [41]-[43].

The current flow through in inductor and the time immigration that show the positive value in switch is closed the current is Lanier on ramps up in the slope of this current is going be positive recorded the voltage inductor and obtain in equations:

$$Imax = \left(\frac{1}{L}\right) * Vin * D * Ts + Imin \tag{1}$$

$$Imin = \left(\frac{1}{L}\right) * Vo * (1 - D) * Ts + Imax \tag{2}$$

By substituting equation (2) into equation (1), we can obtain equation (3), which represents the relationship between the input and output voltages, in addition to the duty cycle. Fig. 3 shows the current behavior over a two-cycle operating period.

$$Imax = \left(\frac{1}{L}\right) * Vin * D * Ts + \left(\frac{1}{L}\right) * Vo * (1 - D) * Ts + Imax$$

$$Imax = \left(\frac{1}{L}\right) * Vin * D * Ts + \left(\frac{1}{L}\right) * Vo * (1 - D) * Ts + Imax$$

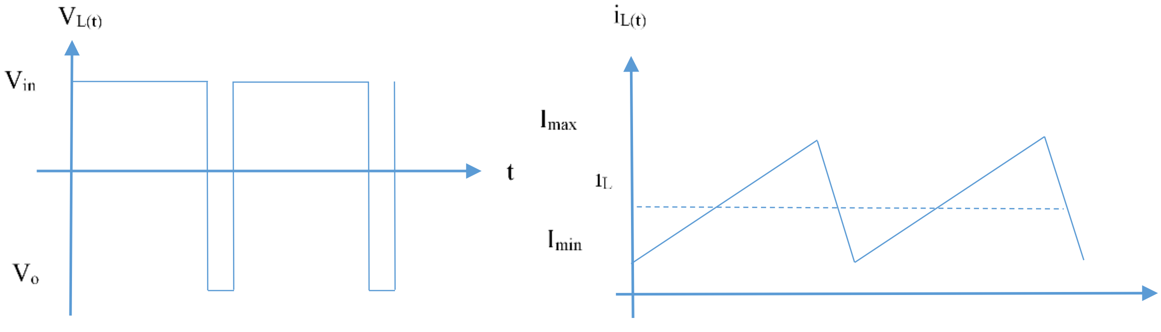
$$0 = \left(\frac{1}{L}\right) [Vin * D * Ts + * Vo * (1 - D) * Ts]$$

$$0 = \left(\frac{[Vin * D * Ts + * Vo * (1 - D) * Ts]}{L}\right)$$

$$0 = Ts[Vin * D + * Vo * (1 - D)]$$

$$0 = [Vin * D + * Vo * (1 - D)]$$

$$-Vin * D = Vo * (1 - D)$$



a. Voltage b. Current

Fig. 3. The voltage across and current flow through in inductor

$$Vo = -Vin\frac{D}{1-D} \tag{3}$$

$$Imax = \left(\frac{1}{L}\right) * Vin * D * Ts + Imin \tag{4}$$

$\Delta IL = Imax - Imax$

$Imax = \left(\frac{1}{L}\right) * Vin * D * Ts + Imin$

$Imax - Imin = \left(\frac{1}{L}\right) * Vin * D * Ts$

$\Delta IL = \left(\frac{1}{L}\right) Ts * Vin * D$

$L = \left(\frac{1}{\Delta IL}\right)\frac{1}{fs} * Vin * D$

$L = \frac{Vin * D}{\Delta IL * fs}$

$L = (Vin * D)/(\Delta IL * fs) = 20 * 0.5/0.1 * 5000 = 10/500 = 1/50 = 0.002 = 2mH$

$$Imin = \left(\frac{1}{L}\right) * Vo * (1-D) * Ts + Imax \tag{5}$$

$Imin = \left(\frac{1}{L}\right) * Vo * (1-D) * Ts + Imax$

$\Delta IL = Imin - Imax = \left(\frac{1}{L}\right) * Vo * (1-D) * Ts$

$\Delta IL = \left(\frac{1}{L}\right) Ts * Vo * (1-D)$

$L = \left(\frac{1}{\Delta IL}\right)\frac{1}{fs} * Vo * (1-D)$

$L = \frac{Vo * (1-D)}{\Delta IL * fs}$

$L = \frac{40 * (1-0.5)}{0.1 * 5000} = \frac{40 * (0.5)}{500} = \frac{20}{500} = \frac{2}{50} = 0.04 = 40mH$

$0.1 = \left(\frac{1}{L}\right) * 20 * 0.5 * 0.0002 + \left(\frac{1}{L}\right) * 40 * (1-0.5) * 0.0002$

$0.1 = \left(\frac{1}{L}\right)[10 * 0.0002 + 20 * 0.0002]$

$L = \frac{[0.002 + 0.004]}{0.1} = \frac{0.006}{0.1} = 0.06 = 60mH$

The type of credit can be converted according to the value of the duty cycle compared with the amount of half to represent the inverter equality. The same voltage is in the converter conversion, while when it is less than half, this means that the converter is stepping down, and the inversion when it is greater than half gives a greater value in the output and is a step-up converter type [42]-[45].

It is possible to express mathematically the relationship between the input and output voltages for the possible states according to the duty cycle using the equation (6).

There are three cases for $\frac{D}{1-D}$ when the value is less than one, another value is greater than one and the last one is when the value is equal to one as shown:

$$Vo = -Vin\frac{D}{1-D} \tag{6}$$

$\frac{D}{1-D} > 1, D > 1 - D, D + D > 1, 2D > 1, D > \frac{1}{2}, \frac{D}{1-D} < 1, D < 1 - D, D + D < 1, 2D < 1,$

$D < \frac{1}{2}, \frac{D}{1-D} = 1/2,\ Vo = -Vin\frac{\frac{1}{2}}{1-\frac{1}{2}}, Vo = Vin\frac{\frac{1}{2}}{\frac{1}{2}}, Vo = -Vin$

The input current waveform for the duty cycle can also be drawn as in Fig. 4. It is possible to express mathematically the relationship between the input and output current for the possible states according to the duty cycle using the equation (7):

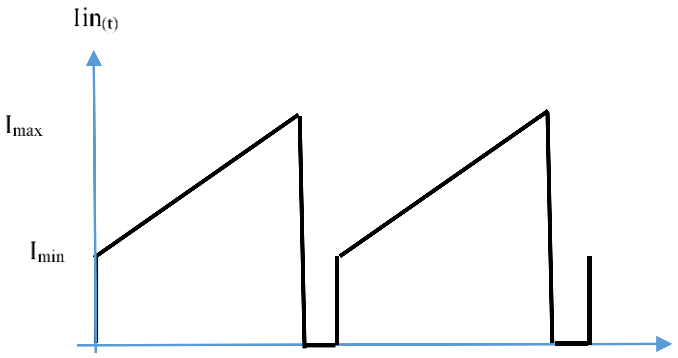


Fig. 4. The input current waveform for the duty cycle

$Vo = -Vin * \frac{D}{1-D}$

$$Iin = Io * \frac{D}{1-D} \tag{7}$$

$Iin = IL * D$

$IL * D = Io * \frac{D}{1-D}$

$IL = \frac{Io}{1-D}$

The current waveform for the electronic switch can be drawn, including the transistor current, as well as the diode current waveform, as shown in Fig. 5:

$\frac{Io}{(1-D)} + \frac{\Delta Ic}{2} = Imax$

$ID = \frac{Io}{(1-D)} * (1-D)$

$ID = Io$

For the capacitor current and voltage that connected with the load in first side and the diode another side that can be show in the equations and Fig. 6:

$Vin = VD + Vo = VD + Vc$

$VD = Vin - Vo$

$ic(t) = iD(t) - Io$

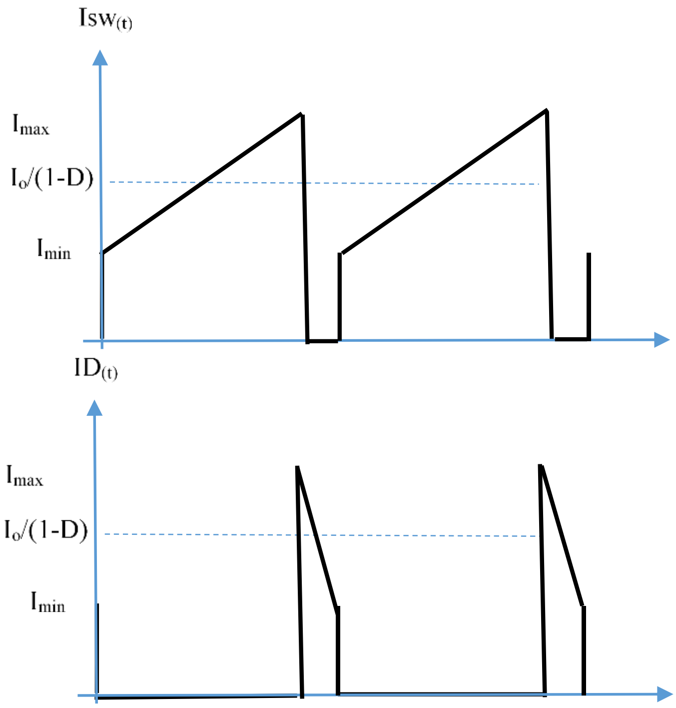


Fig. 5. The Transistor current and diode waveform for the duty cycle

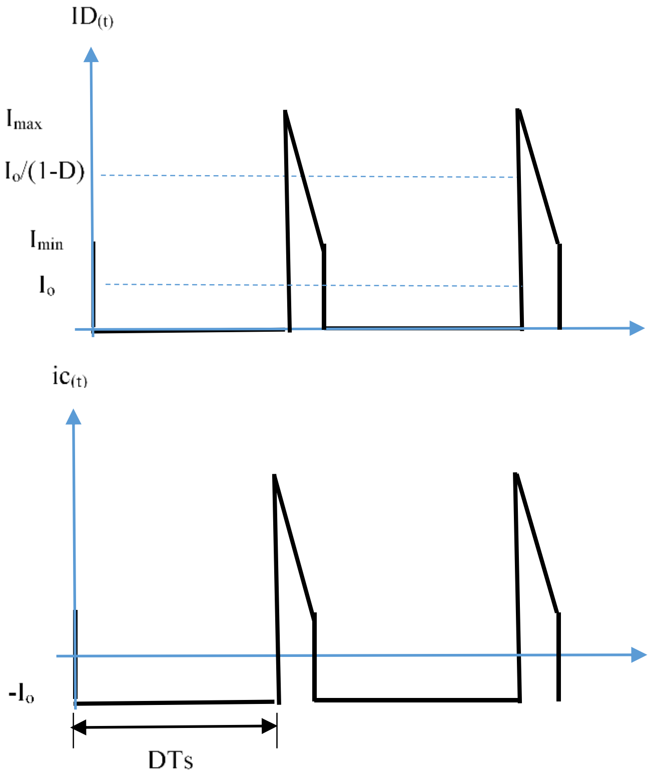


Fig. 6. capacitor and diode current waveform for the duty cycle

$$\Delta Vo = \frac{Io * D * Ts}{C}$$

$$C = \frac{Io * D * Ts}{\Delta Vo} = \frac{Io * D}{fs * \Delta Vo}$$

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To build and design the required converter model, a model of a DC to DC converter of the step-up type or what is called a post converter is taken and a rearrangement is made to obtain the required model. As a first step in the construction and design steps, the direction of the diode is changed to make a rotatable for the diode. The second step is to replace the coil with the electronic switch, an IGBT transistor, and the electronic switch must be opposite to the direction of the source for a reason so that the switch does not remain in a connected state throughout the operating period. Its state can be changed from open to closed by a series of conversions according to appropriate trigger pulses to obtain the required output [46]-[48]. Then the first problem appears when the switch is connected directly to the source as in a buck converter or step-down converter, so its solution requires adding a capacitor with a high value, for example 4500 microfarads before the switch in parallel with the source. While a capacitor was added in parallel with the source, another problem appeared and it needs to be solved by adding a very small resistance, for example 0.1 ohm, in series with the source to solve the problem of the source not being shorted by the capacitor when connected in parallel with a DC source. The relationship between the input and output of the transformer after rearranging is $Vout/Vin = -D/(1-D)$, while before rearranging it was $Vout/Vin = 1/(1-D)$ [49]-[51].

The first mode when the switch is connected the current is only in one direction the coil is charged while the second branch does not allow the current to pass because the diode is reverse biased. The second mode when the switch is opened the coil begins to discharge so that it is in the same direction with the charging current which is the discharge current and the voltage is opposite to the direction of the current. That is, the current flows from top to bottom in the charging and discharging states of the coil. The discharge current of the coil branches out to the resistive load and the capacitor connected in parallel with the load and the direction of the load current is from bottom to top. According to Ohm's law the voltage is opposite to the direction of the current, so the output of the transformer is negative and the current continues to flow through the diode because it is forward biased and allows the current to pass through it.

Design of Buck-Boost Inverter, to design a converter of this type with a negative output, called an inverter, the converter's output voltage can be increased or decreased by the input value. The design begins by determining the system parameters, which represent the input voltage (Vin), which represents the available power supply voltage, and the load voltage, which is the desired output voltage (Vout). The output current (Iout) can be determined by determining the load, and the current changes with changes in the load.

To design the model requires an overview of diagram of the inverting buck-boost converter, derive the i/o equation for voltage and current, derive the design equations for L and derive sizing for C, the diode sizing and transistor sizing. It is suggested to conduct a preliminary test of a non-inverting step-up converter consisting of a 20V input voltage that is to be doubled to 40V without inverting the signal. The ideal duty cycle, which depends on the input-to-output ratio, can be calculated mathematically from the equation in Equation (8):

$$\text{Duty} = -\frac{\text{Vout}}{(\text{Vin} - \text{Vout})} \tag{8}$$

$$Duty = -Vout\ /\ (Vin - Vout) = -40/(20-40) = -40/-20 = 1/2 = 0.5 * 100\% = 50\%$$

Model design requires determining the switching frequency, which depends on the power density and noise from electromagnetic interference. In the current work, Fsw =5000Hz. After finding the duty cycle, calculate the appropriate inductance value for this model. The equation includes several concepts, including the switch voltage VQ, duty cycle, switching frequency, input voltage VIN, time T, load current Iout, and the inductor ripple level di as a percentage of the load current. Equation (9) can be used:

$$L = \frac{Ton * (Vin - VQ)}{(\%di * Iout)} \tag{9}$$

$Ton = Duty / Fsw = 0.5 / 5000Hz = 0.0001sec = 100usec$

When, $VQ = 0.25V$ and $\%di = 25\%$ thus:

$$L = Ton * (Vin - VQ) / (\%di \, X \, Iout) = 100usec * (20V - 0.2V) / (0.25 * 4A) = 0.00198\, H = 1.98\, mH$$

$$C = \frac{D}{R * dVo * Fsw} \tag{10}$$

$$C = \frac{0.5}{10 * 0.25 * 5000} = \frac{0.5}{12.500} = 0.04F = 40microF$$

It is possible to conduct tests with default values and change them to obtain a specific output voltage, while the mathematical relationships of the transformer can be used, through which the appropriate design can be made to obtain the electrical quantities required to supply the load. In a preliminary test, an input voltage of 20 volts, a capacitance of 40 microfarads, and a coil of 1.98 millinery capacity can be chosen with a 50% (which represents duty cycle) pulse switching on and off. We obtain an output voltage equal to the input, inverse of the signal. When the output value is to be increased or decreased from the value in the transformer input, the switch opening and closing period is changed from 50% to 20% or 70%, and thus a variable voltage can be obtained from a fixed voltage, inverse of the signal. The proposed converter can provide safe operation and protection for power electronic devices during load fluctuations. It also provides isolation during no-load or overload by not supplying power. It also provides adequate gain to cover the load according to the switching system and fast dynamic performance. It also provides smooth switching between the two operating states of the converter, whether it is a step-down or a step-up. To evaluate the capability of the proposed converter, appropriate tests are conducted for several similar applications under different operating conditions.

3. Simulation Modeling of DC-DC Converter

In this section there are two part first part that show the system model of the step-up converter before the arrangement. It used to product the second part include inverting buck-boost inverter. A voltage converter is being developed to generate a negative voltage output, i.e., it has the ability to invert the output signal. The converter's input is connected to a DC voltage source, and is intended to generate a higher or lower voltage, depending on the application requirements, while maintaining the inverting output signal. This converter is used in many fields, most notably those powered by batteries, such as portable devices, where the required voltage varies depending on the load. Converters regulate and provide a stable and suitable voltage for the batteries. A study and analysis of these converters will address these challenges by building and designing a simulation model to generate a voltage suitable for covering the load or charging the batteries, operating efficiently and reliably under various operating conditions. Its effectiveness can be verified through proposed tests covering operating conditions suitable for real-time operation.

Fig. 7 represents the system model of the step-up converter before the arrangement. The input voltage was 20 volts and was doubled by using a designed step-up converter. The coil values were (40 millinery) while the capacitor value was 1000 microfarads and with a resistive load of 10 ohms. The results showed obtaining a positive output voltage of 40 volts as shown in the Fig. 7.

Fig. 8 represents the system model of the inverting buck-boost inverter after installation where the input voltage was 20 volts. To obtain the same value but with a negative sign, it is suggested to use the inverting buck-boost inverter and design it so that the values of the coil were (0.5 milli) while the value of the capacitor was 220 microfarads and with a resistive load of 10 ohms and a small resistance of about 0.1 ohms connected in series with the source and a capacitor (4500 microfarads) was added in parallel with the source. The results showed obtaining an output voltage of negative 20 volts as shown in the Fig. 8.

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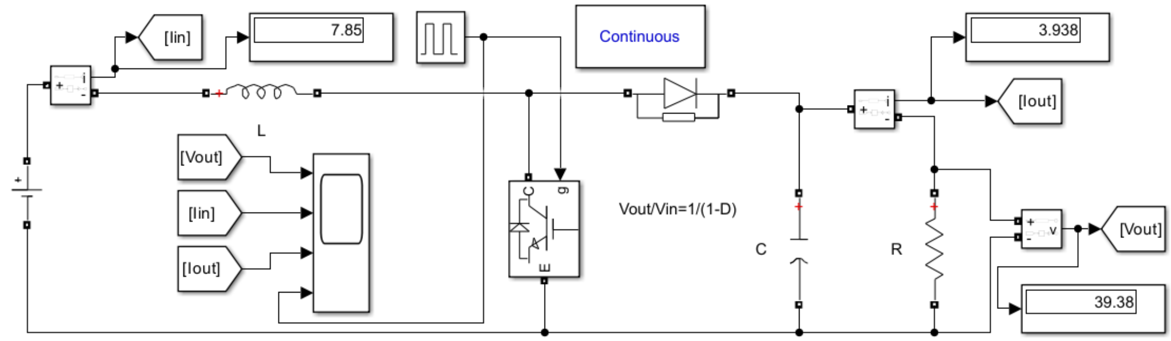


Fig. 7. system model of the step-up converter before the arrangement

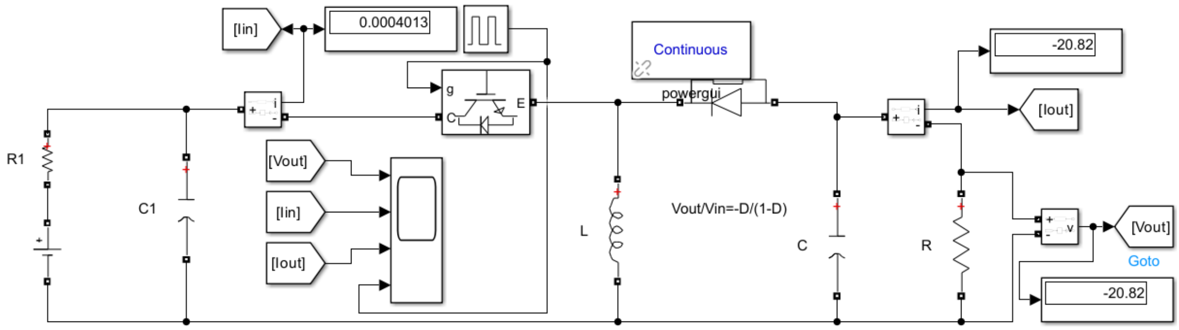
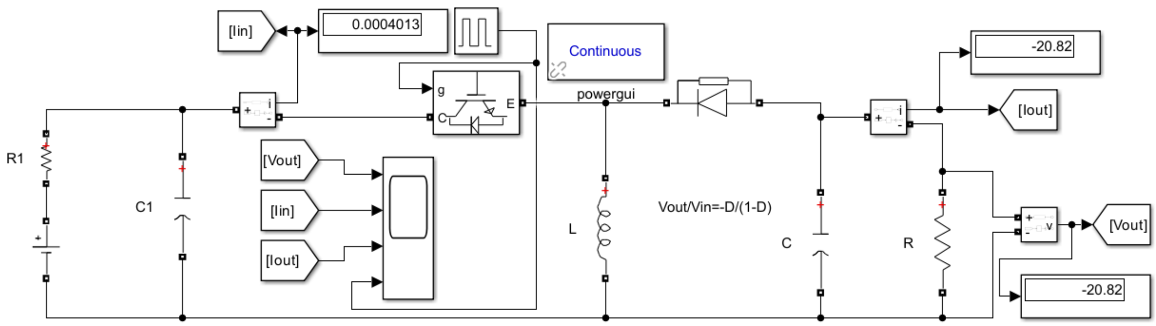


Fig. 8. system model of the inverting buck-boost inverter

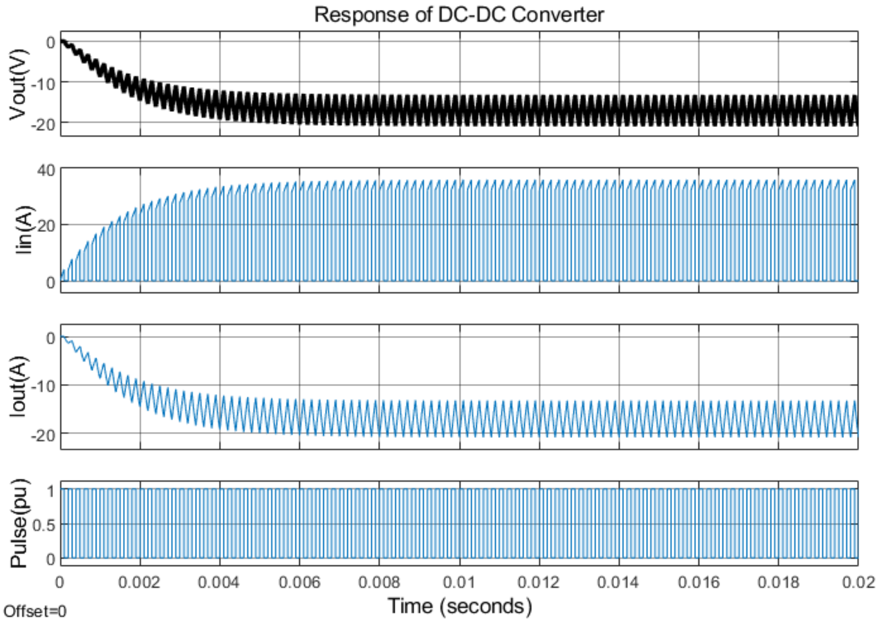
4. Simulation Modeling and Results of the Inverting Buck-Boost Inverter

In the current study, the researchers present a simulation model based on a mathematical representation of electronic power converters. By conducting tests, the system's behavior can be identified under different operating conditions and dynamic analysis. Electronic power converters come in three forms: step-up, step-down, and step-down. Simulation can help us understand the behavior of the converter, as well as dynamic analysis and response.

Conducting tests using the model to obtain lower and higher values of the input voltage with the inverting property. The tests included the cases shown in the table, which included cases in which the load was changed to identify the amount of the system's output and input current. Test cases included changing the duty cycle to identify the possibility of raising and lowering the converter's output value with a fixed input value with a variable output with the inverting property. It is also possible to change the values of the converter components, such as the coil or capacitor values, and to observe the changes in the electrical quantities of the system's input and output. The variable load draws a variable current. This can be verified by suggesting three values for the resistive load, including one ohm, 10 ohms, and 20 ohms. The simulation can be performed as in the model in Fig. 9, Fig. 10, Fig. 11 and the simulation results can be recorded in Table 1.

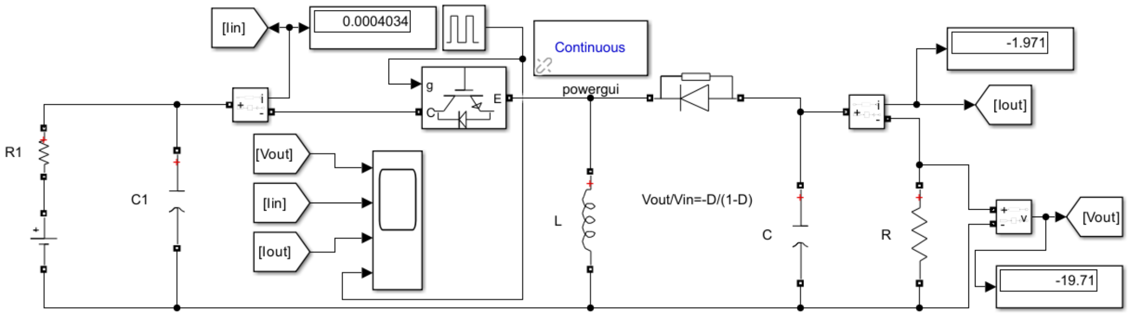


a. system model

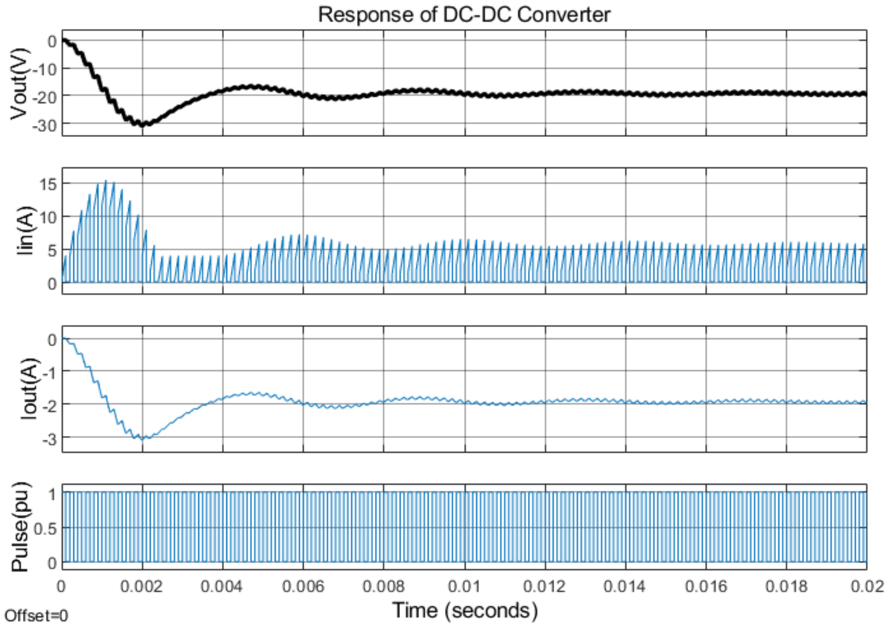


b. simulation response

Fig. 9. Simulation of inverting buck-boost inverter with $R = 1\ ohm$



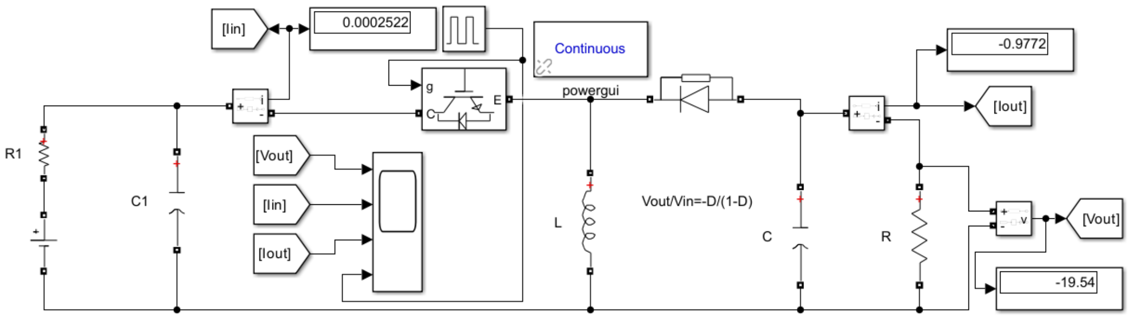
a. system model



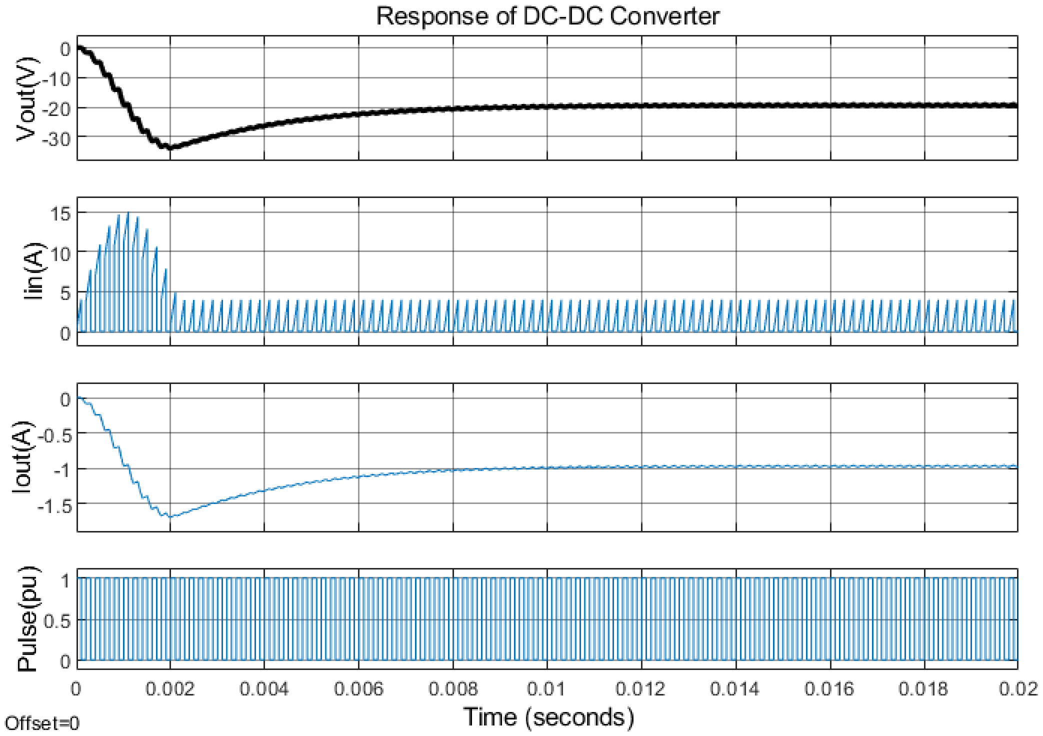
b. simulation response

Fig. 10. Simulation of inverting buck-boost inverter with $R = 10$ ohm

The duty cycle changes by a percentage, which changes the value of the transformer output voltage. To verify this, three test cases were proposed, including an initial value to give the same value at the output with the signal inversion feature, in addition to two other values that include a higher value and a value less than 50%, for example 20% and 70%. The simulation can be performed as in the model in Fig. 12, Fig. 13, Fig. 14 and the simulation results can be recorded in Table 2. Simulation of duty cycle for inverting buck-boost inverter shown in Fig. 15.

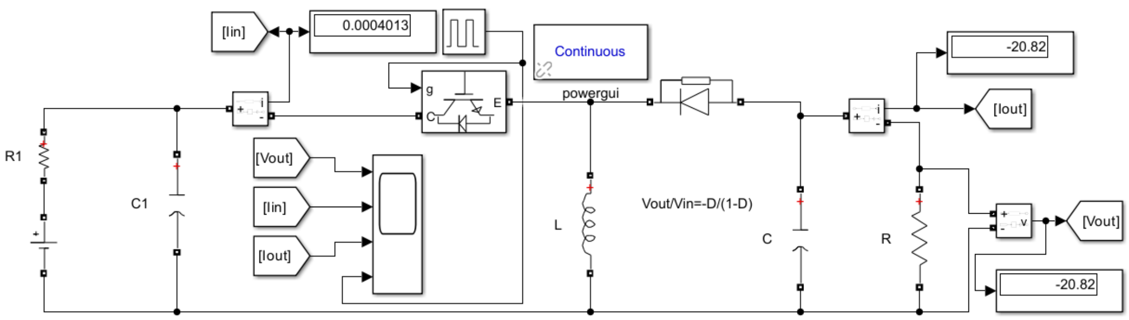


a. system model

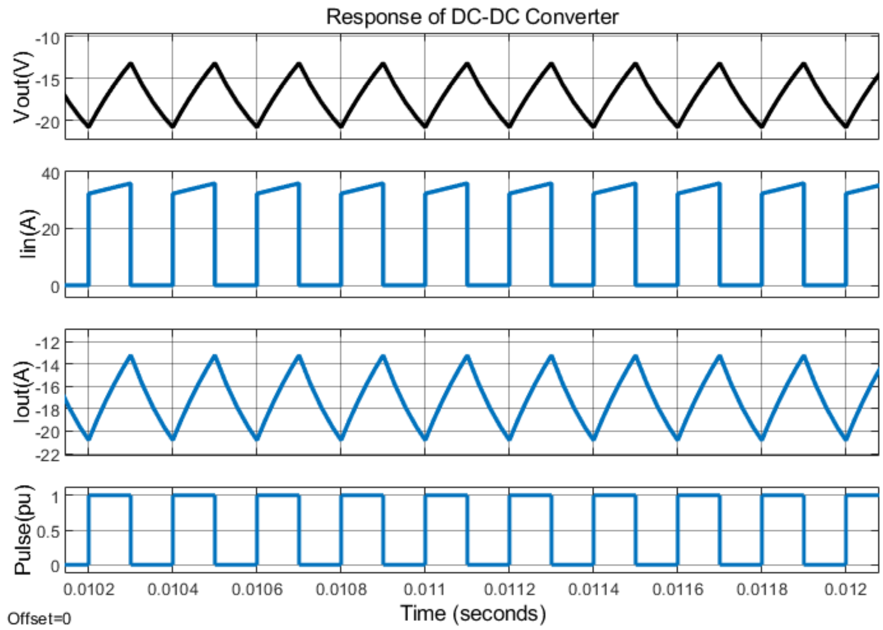


b. simulation response

Fig. 11. Simulation of inverting buck-boost inverter with $R = 20\ ohm$

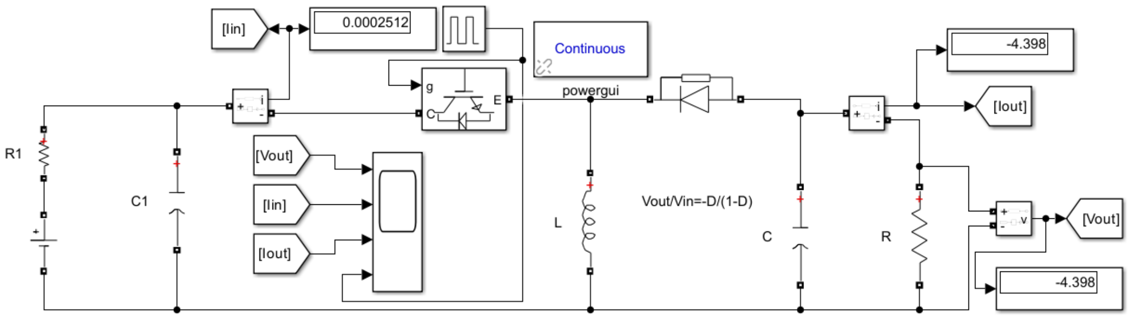


a. system model

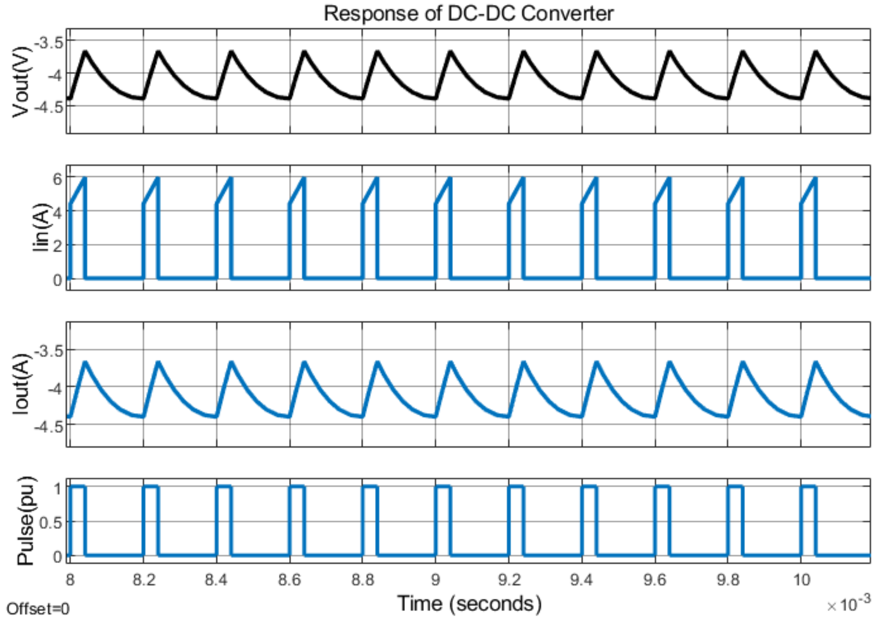


b. simulation response

Fig. 12. Simulation of inverting buck-boost inverter with D=50%



a. system model



b. simulation response

Fig. 13. Simulation of inverting buck-boost inverter with $D = 20\%$

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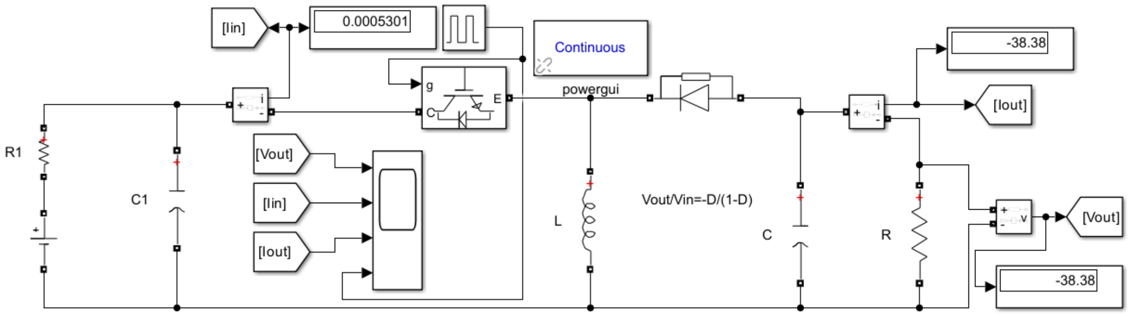
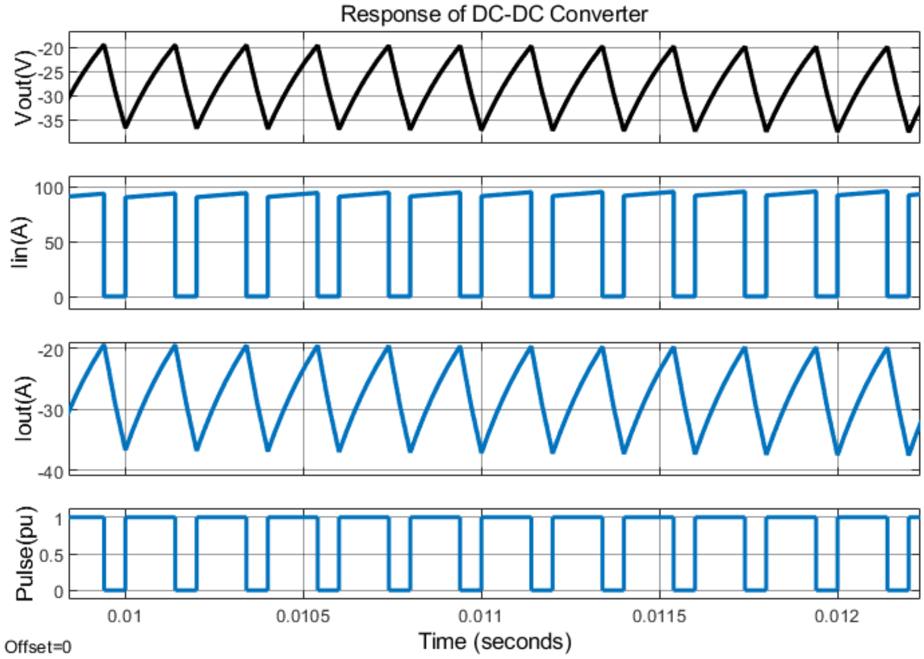


a. system model



b. simulation response

Fig. 14. Simulation of inverting buck-boost inverter with $D = 70\%$

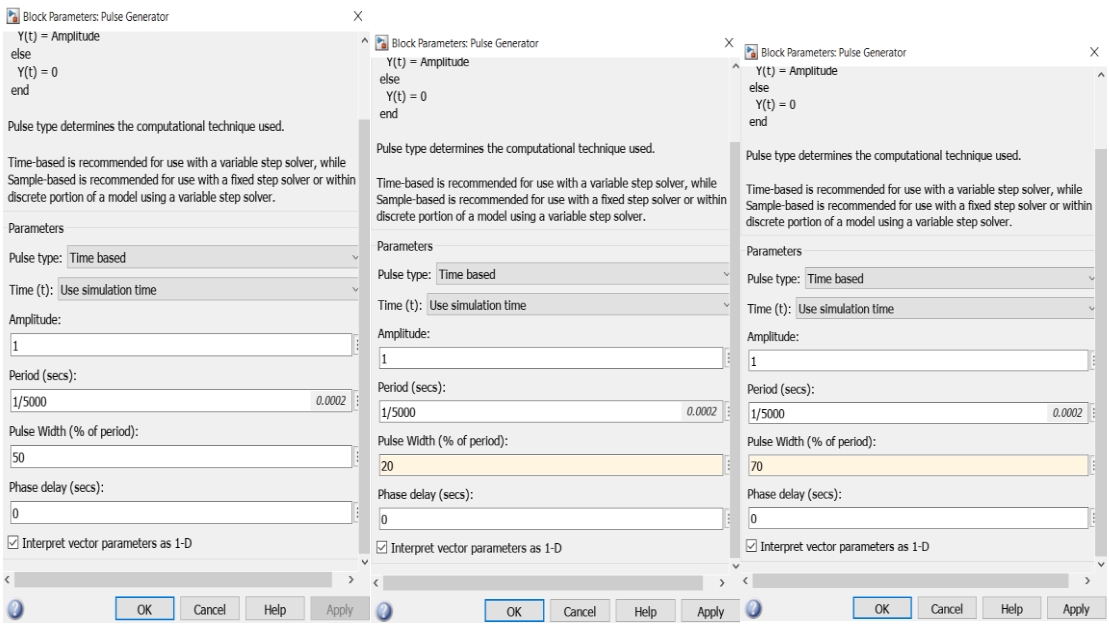


Fig. 15. Simulation of duty cycle for inverting buck-boost inverter

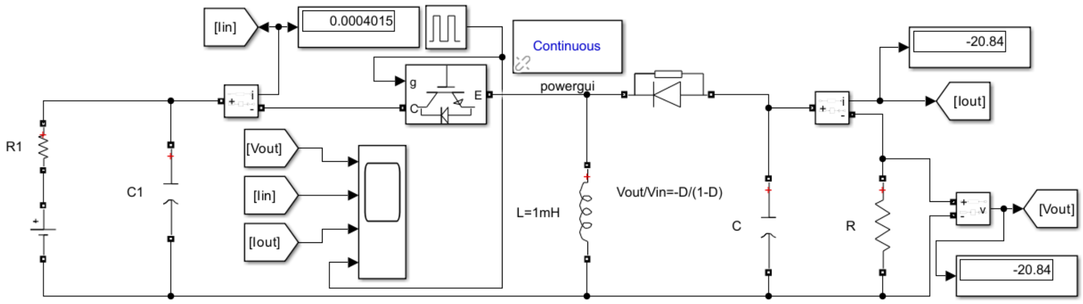
Table 1. Simulation response of inverting buck-boost inverter with variable load (R)

R load (Ω)	inverting buck-boost inverter		
	Iin(A)	Iout(A)	Vout(V)
1Ω	0.0004013	-20.82	-20.82
10Ω	0.0004034	-1.971	-19.71
20Ω	0.0002522	-0.9772	-19.54

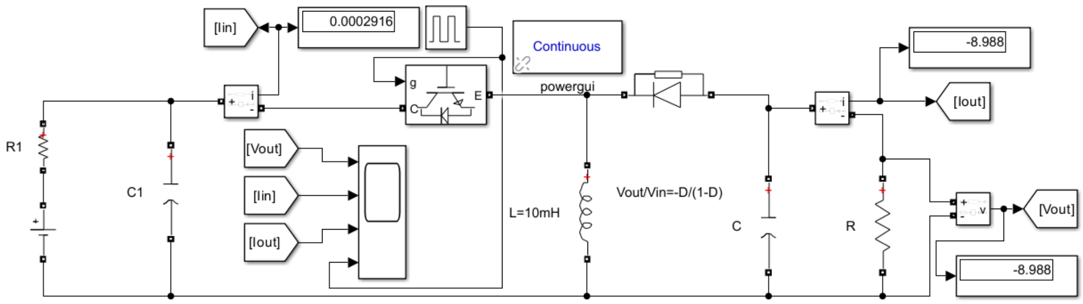
Table 2. Inverting buck-boost inverter with different value of duty cycle (D)

Duty cycle (D)	inverting buck-boost inverter		
	Iin(A)	Iout(A)	Vout(V)
20	0.0002512	-4.398	-4.398
50	0.0004013	-20.82	-20.82
70	0.0005301	-38.38	-38.38

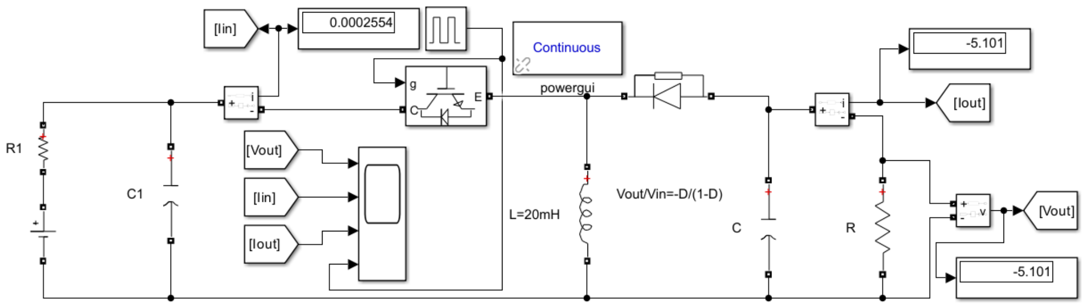
Other tests can be performed by changing the values of the transformer components such as the values of the coil (0.5, 5, 50) observing the changes in the electrical quantities of the system input and output. The simulation can be performed as in the model in Fig. 16 and the simulation results can be recorded in Table 3. Inverting buck-boost inverter shown in Fig. 17, Simulation response of inverting converter with $Vo = -Vin$ shown in Fig. 18, Simulation response of Boost inverting at $Vo > Vin$ shown in Fig. 19, Simulation response of buck inverting at $Vo < Vin$ shown in Fig. 20.



a. system model with $L = 1\ mH$

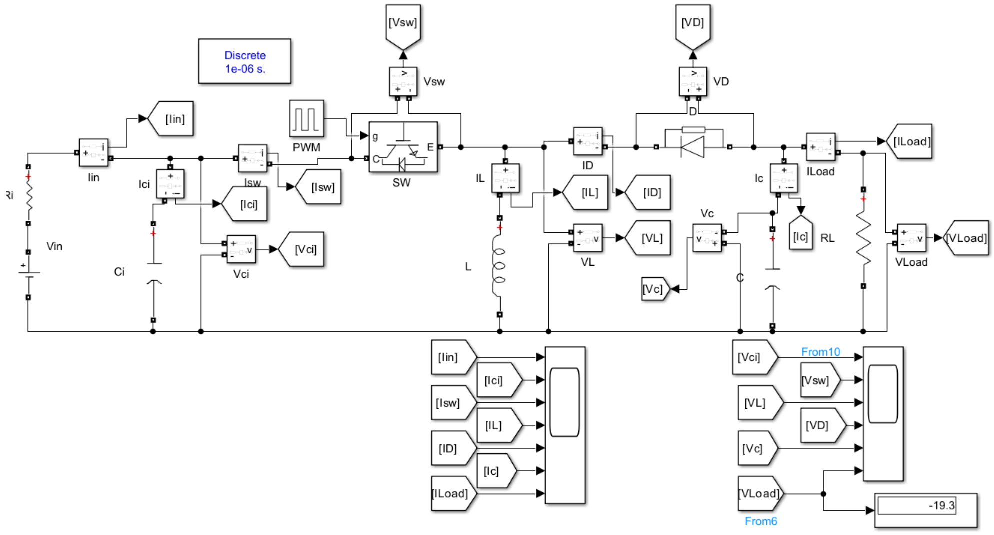


b. system model with $L = 10\ mH$

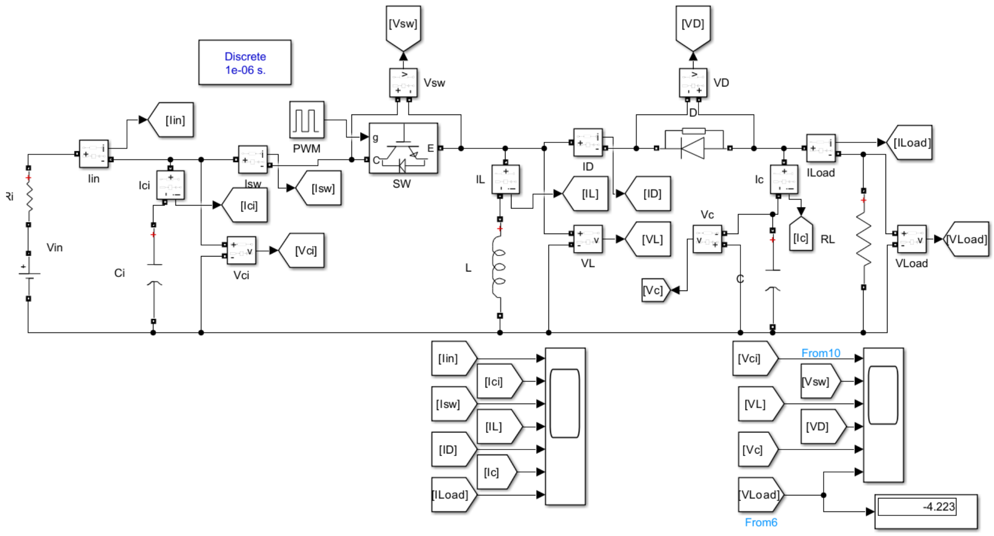


c. system model with $L = 20\ mH$

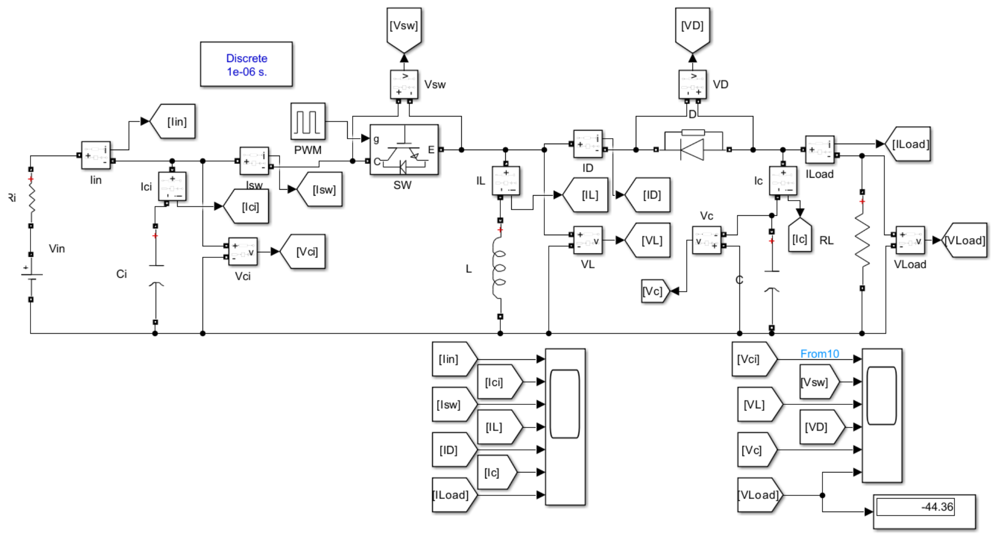
Fig. 16. Simulation response of inverting buck-boost inverter with L (1,10&20) mH



a. inverting converter with $Vo = -Vin$

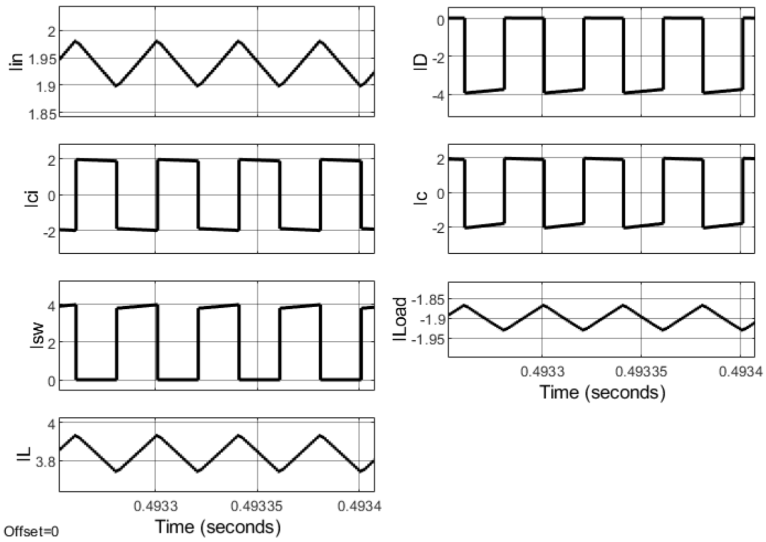


b. buck converter at $Vo < Vin$ with inverting

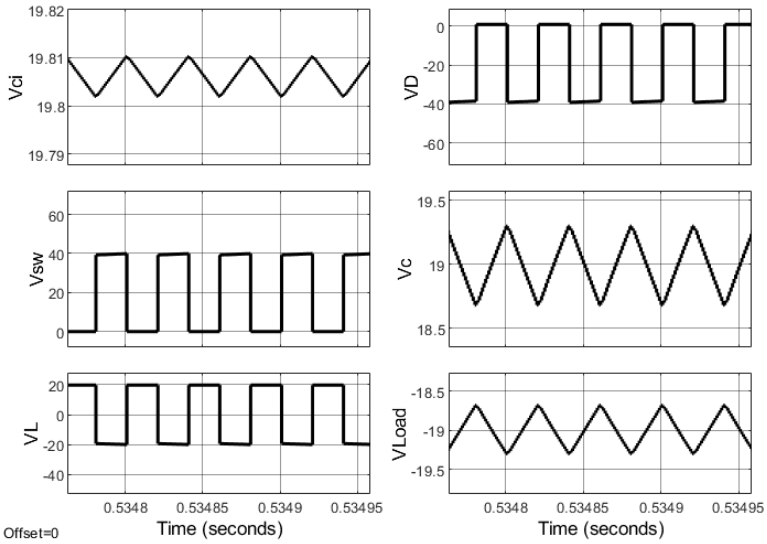


c. Boost converter at $Vo > Vin$ with inverting

Fig. 17. Inverting buck-boost inverter

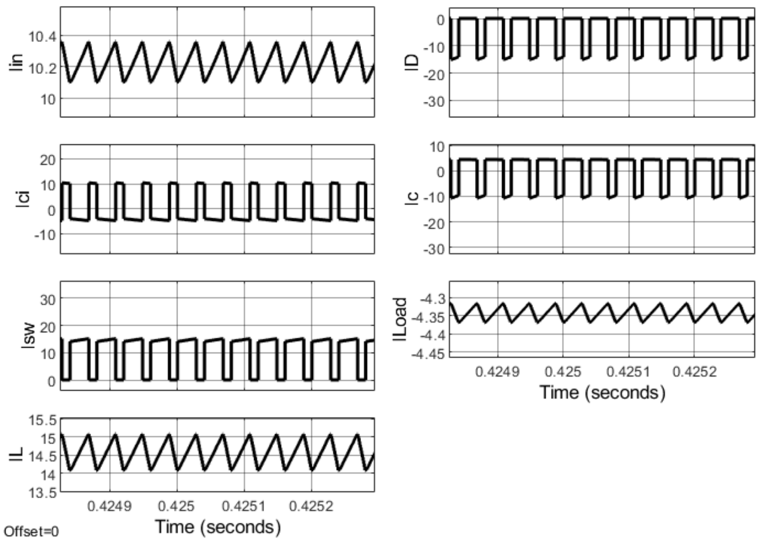


a. current

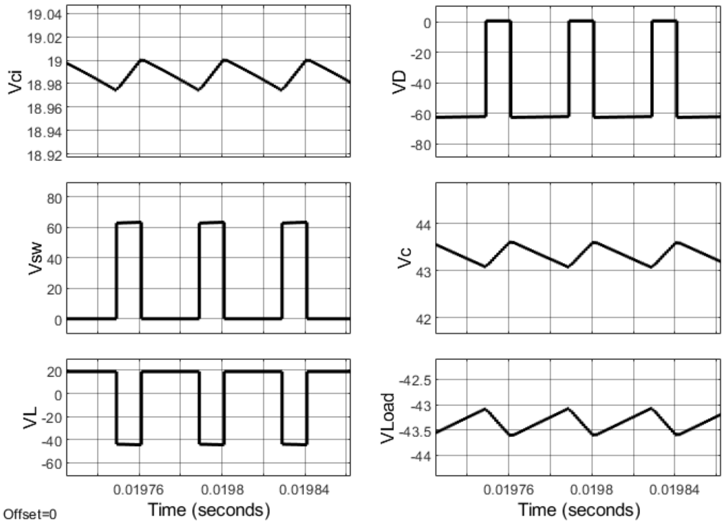


b. voltage

Fig. 18. Simulation response of inverting converter with $Vo = -Vin$

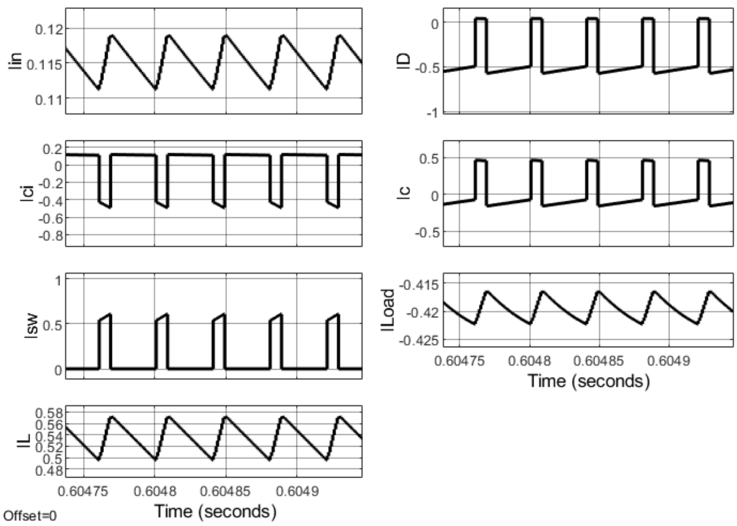


a. current

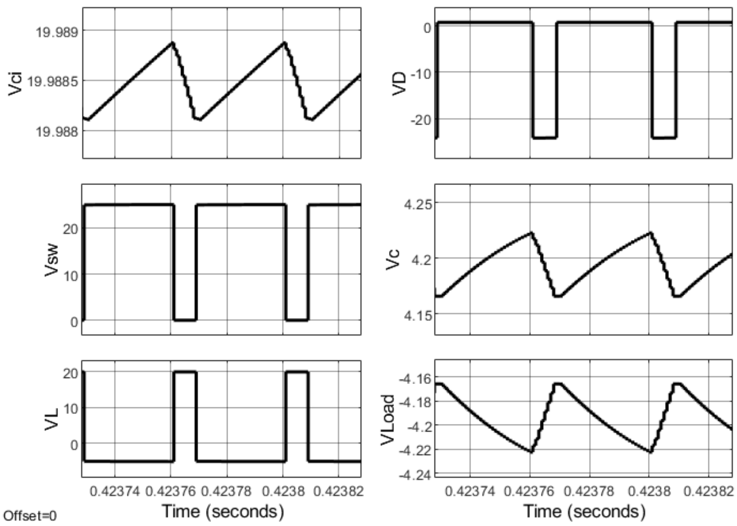


b. voltage

Fig. 19. Simulation response of Boost inverting at $Vo > Vin$



a. current



b. voltage

Fig. 20. Simulation response of buck inverting at Vo<Vin

Table 3. Inverting buck-boost inverter with different value of L $(1{,}10\&20)$ mH

L (mH)	inverting buck-boost inverter		
	Iin(A)	**Iout(A)**	**Vout(V)**
1	0.0004015	-20.84	-20.84
10	0.0002916	-8.988	-8.988
20	0.0002554	-5.101	-5.101

5. Conclusion

This type of transformer was identified in addition to knowing its behavior in different operating conditions. After proposing the simulation model, tests were conducted to verify the effectiveness of using the transformer to obtain the required quantities to cover the load with the appropriate voltage. The results proved the effectiveness of the designed model and its use was verified to transform the voltage with quantities higher or lower than the input voltage value in addition to the specificity of signal inversion. The transformer can be used in applications that require changing the voltage value with the property of inverting the output signal. From the simulation results, it was shown that there is a change in the amount of current drawn from the source with the change in the output voltage and current according to the proposed cases shown in Table 1, Table 2, and Table 3.

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