Design and Analysis of Two Switch Boost Converter.

[1]D.KIRAN KUMAR, [2]B.SANKEERTHANA, [3]K.C.P.LAHARI, [4]K.SUDHA RANI, [5]Dr. G.SAMBASIVA RAO

[1]STUDENT , [2]STUDENT , [3]STUDENT , [4]STUDENT, [5]PROFESSOR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING,

R.V.R & J.C. COLLEGE OF ENGINEERING, GUNTUR, ANDHRA PRADESH , INDIA.

ABSTRACT

High-gain DC-DC converters are becoming important in renewable energy systems, especially in solar power setups. This project introduces a new type of boost converter that does not use transformers or coupled inductors but still delivers a high-voltage output from a low-voltage input. It is designed to work well with energy sources such as solar panels or fuel cells, where the input voltage is usually low. Its simple design uses two switches, which are controlled by a single Pulse-width modulation (PWM) signal. This makes the entire system smaller, less expensive, lighter, and easier to manage. Compared with other similar converters, this method performs better in almost every area. For example, it can boost the input voltage up to approximately 15 times at a 60% duty cycle, and nearly 21 times at a 70% duty cycle. The efficiency is also impressive, ranging from 92% to 95%, which means that very little energy is wasted. Overall, this converter offers a reliable, efficient, and practical solution for renewable energy systems that require a high-voltage output from a low- voltage source.

KEYWORDS: *MATLAB software, Renewable energy system, high gain boost converter, dc-dc converter.*

INTRODUCTION:

High-gain DC-DC converters are really useful when you need to turn a small amount of electrical energy (low voltage) into something much stronger (high voltage). This is especially important in things like solar panels, electric vehicles, robots, and other modern systems that relay on clean energy. Since devices like solar panels and fuel cells usually don't produce a lot of voltage on their own, we need converters to boost that energy to a level that can actually power things we use at home or in industries.

These converters are made up of parts like coils (inductors), storage units (capacitors), switches and diodes. They all work together to first store energy and then push it to a higher voltage. Think of it like filling a bucket and then pouring it into a tank at a higher level.

In small power networks called DC microgrids, these converters help keep the voltage steady. Modern systems often use a mix of supercapacitors and converters to make things more efficient. When these microgrids work on their own (without connecting to the main power grid), they also use something called an inverter along with the converter to power everyday appliances that need AC (alternating current).

People are moving away from older boost converters because they have some issues they put a lot of stress on parts, create unwanted electrical noise, don't handle input power smoothly, and aren't very efficient when power demand is low. That's why these new high-gain converters are becoming more popular they solve most of these problems and work much better in real-world situations.

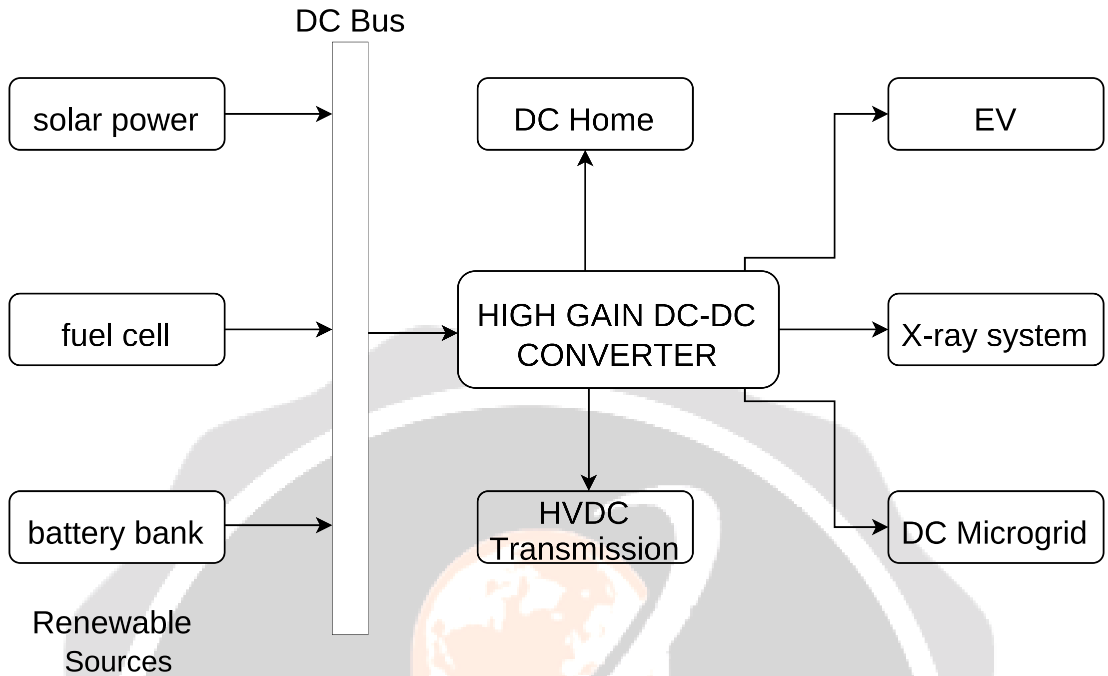
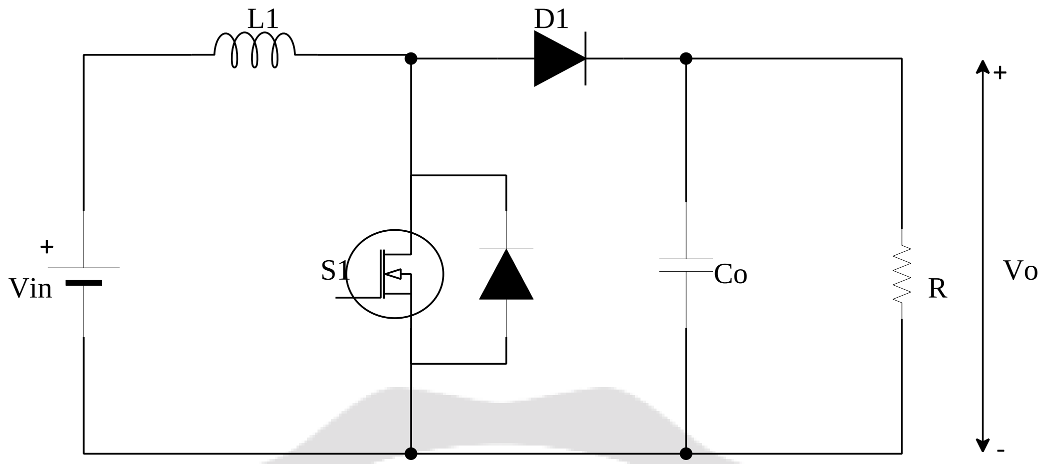


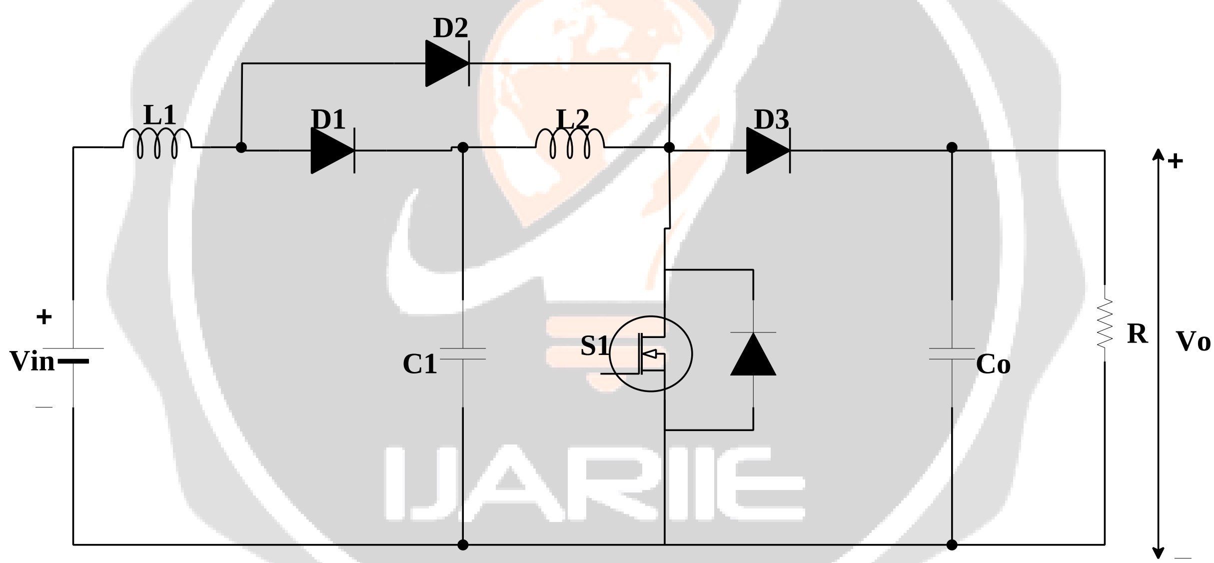
FIGURE 1. DC energy system.

DC-DC converters act like a middleman between the power source and the device or system that needs power (the load). These converters come in two main types: isolated and non-isolated. The traditional type, called a boost converter (like the one shown in Figure 2a), has to work very hard at high settings when used in systems like microgrids. But when it runs at these high levels, it puts a lot of strain on the components, causing both the current and voltage to rise too much.

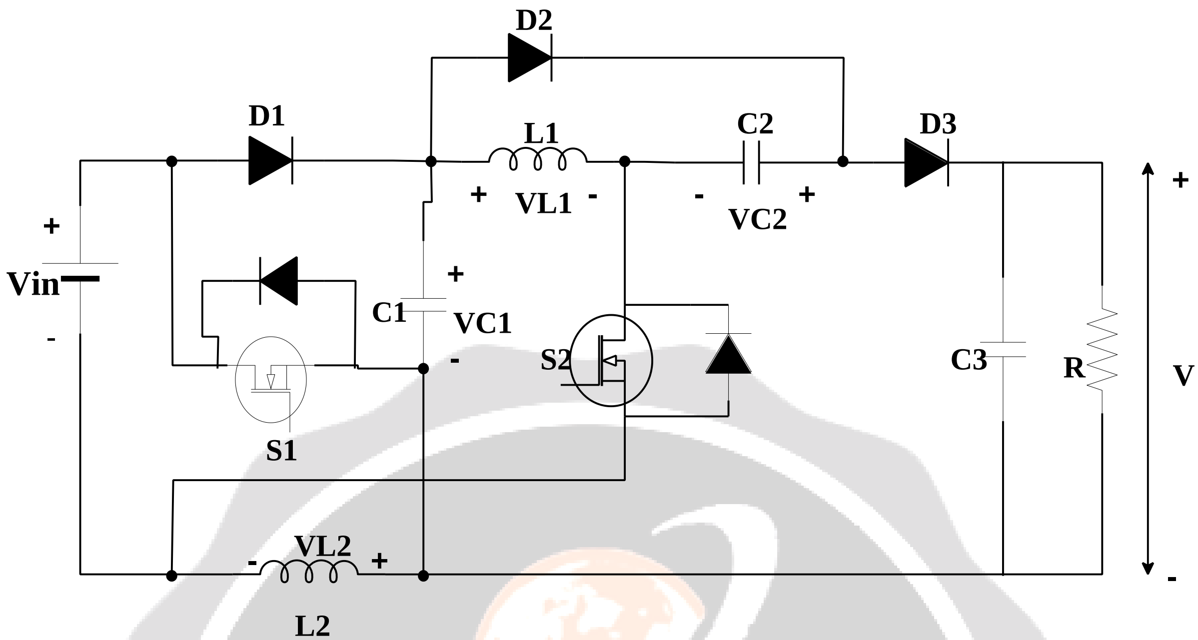
On top of that, as the boost converter works harder, some parts inside it like the capacitor and inductor start to resist the flow of electricity more (this is called parasitic resistance or ESR). That resistance causes energy to be lost as heat, which means the converter can't boost the voltage as effectively, and it becomes less efficient overall.



(a)



(b)



(c)

FIGURE 2. (a) Conventional boost converter (b) Conventional quadratic boost converter (c) Proposed high gain boost converter.

DC-DC converters that don't isolate the input from the output are called non-isolated converters, and they can be further divided into two types: coupled inductor and non-coupled inductor designs. On the other hand, isolated converters use a high-frequency transformer to separate the input side from the output side. This prevents direct current flow between the two sections, which can be important for safety and system protection. However, using a transformer makes the converter bigger and more expensive. That's why isolated converters are typically used in high-power systems that need electrical separation between the source and the load.

Coupled inductor converters are good at achieving high voltage output even at lower power levels (duty cycles), but they run into problems at higher duty cycles like stress on the switches, power losses, and lower efficiency due to energy leakage.
Non-isolated converters are preferred when there's no need to separate the input and output. Some of these use special networks instead of regular inductors to achieve high voltage gains. But they often need more components, like multiple capacitors and diodes, to reach those higher voltages. One type, which uses a three-winding inductor, can offer a wide range of output voltages, low electrical noise, and is easier to control with simple electronics.

This paper introduces a new type of non-isolated, non-coupled inductor-based high-gain boost converter, and it comes with several great features:

- It delivers high voltage gain, higher output voltage, and runs in continuous current mode (CCM), which makes it ideal for medium to high-power systems like solar panels or electric vehicles.
- The converter can increase voltage by about 15.62 times at a 0.6 duty cycle, and up to 20.98 times at 0.7, which is quite impressive.
- It has a high efficiency between 92% and 95% so very little energy is wasted.
- It only uses two switches, and they experience lower voltage stress than the overall output, which makes them last longer. Even better, it only needs one control signal (PWM) to operate both switches, making the system easier to manage and cheaper to build.
- Since it doesn't use a coupled inductor, it avoids problems like energy leakage and stress on switches that usually happen at high duty cycles.

PROPOSED CONVERTER AND OPERATIONAL MODE:

The design of the new high-gain boost converter is shown in Figure 2(c). It uses two coils (L1 and L2), three diodes (D1, D2, and D3), three capacitors (C1, C2, and C3), and two switches (S1 and S2). Both switches are run by the same control signal (PWM), which helps keep things simple and reduces the need for extra control circuits.

This converter is built to give a big voltage boost while staying energy efficient, which makes it a great option for powering things that need medium to high amounts of power like solar systems or electric vehicles.

In the next sections, we'll look at how this converter works in two different ways: when current flows continuously (CCM) and when it flows in short bursts (DCM). The CCM and DCM modes of operation of a proposed converter are explained in the following sections:

A.CONTINUOUS CONDUCTION MODE:

The converter works in two basic modes, depending on the switching signal: when the switches are ON and when they are OFF. For the converter to work correctly, both switches (S1 and S2) need to turn on and off at the same time. In Continuous Conduction Mode (CCM), the current keeps flowing smoothly through both inductors without stopping. During this mode, energy from the power source is sent into the inductors, which causes the current in them to increase. This steady flow of energy helps boost the voltage. Figure 3 shows the waveforms for the current in the inductors and the voltage across the capacitors during CCM operation.

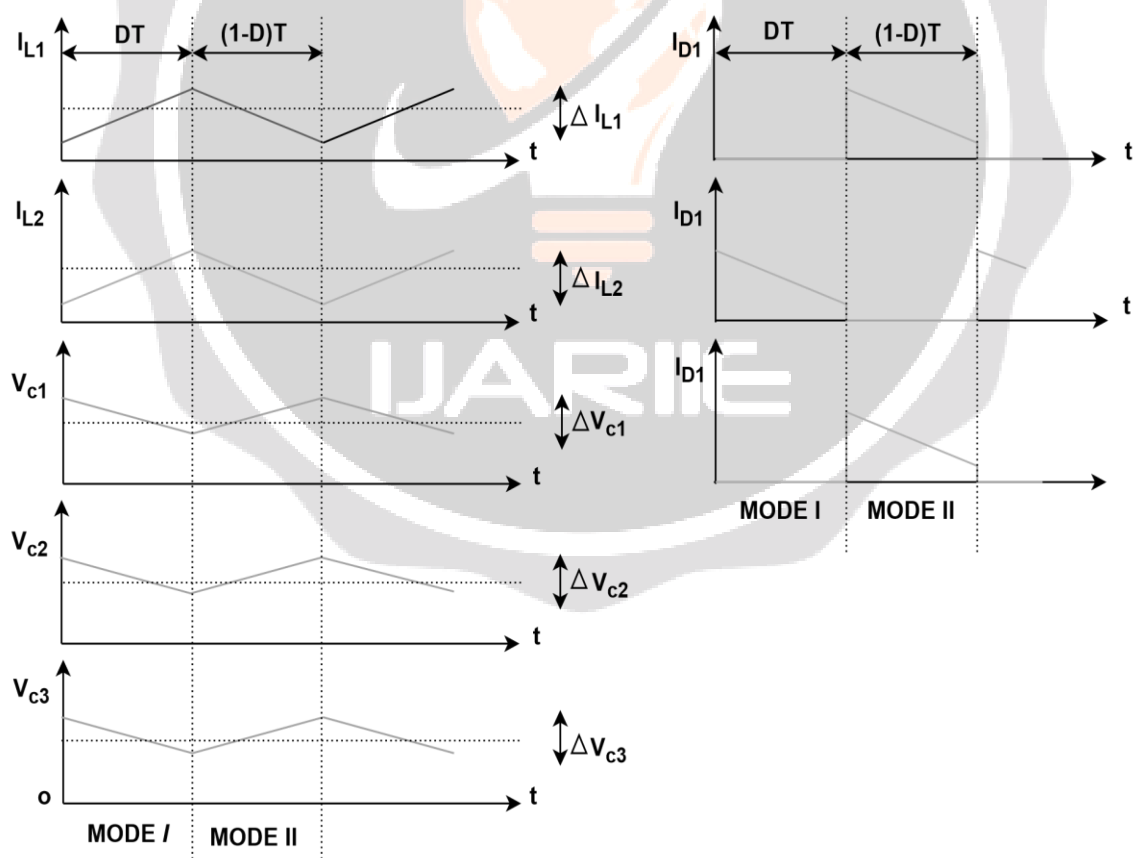


Fig 3. Related waveform in CCM mode.

1)Mode-1 (0 ≤ t ≤ DT):

In mode-1 when both the switches (*S*1 and *S*2) are turned on, the diode (*D*1 and *D*3) becomes reverse biased while the diode *D*2 becomes forward biased. Figure 4 shows an analogous circuit diagram for a converter's first mode of functioning. The switch-on mode equations in CCM (continuous conduction mode) were found an equivalent circuit shown below:

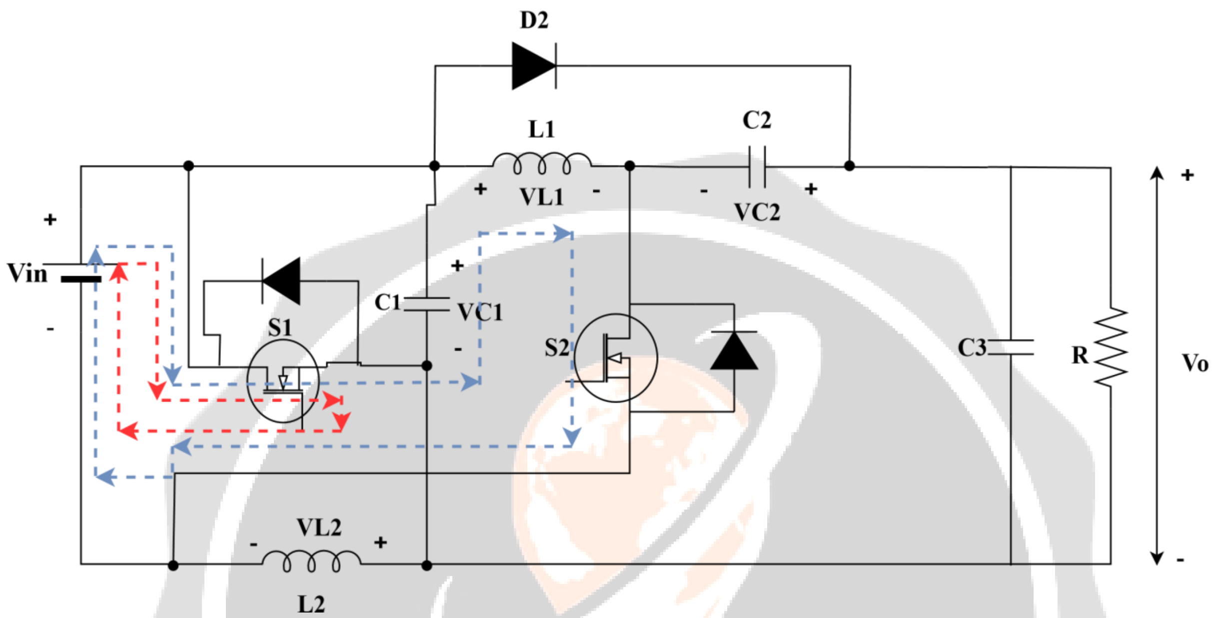


Fig 4. Equivalent circuit for switch-on mode of operation

2) Mode-2 (DT ≤ t ≤ T):

The equivalent circuit shown in Figure 5 illustrates the converter switch-off mode operation. In mode 2, when switches (*S*1 and *S*2) are turned off, the diode (*D*1 and *D*3) will conduct while the diode *D*2 will becomes reverse biased and energy stored in passive components of the converter is transmitted to the load.

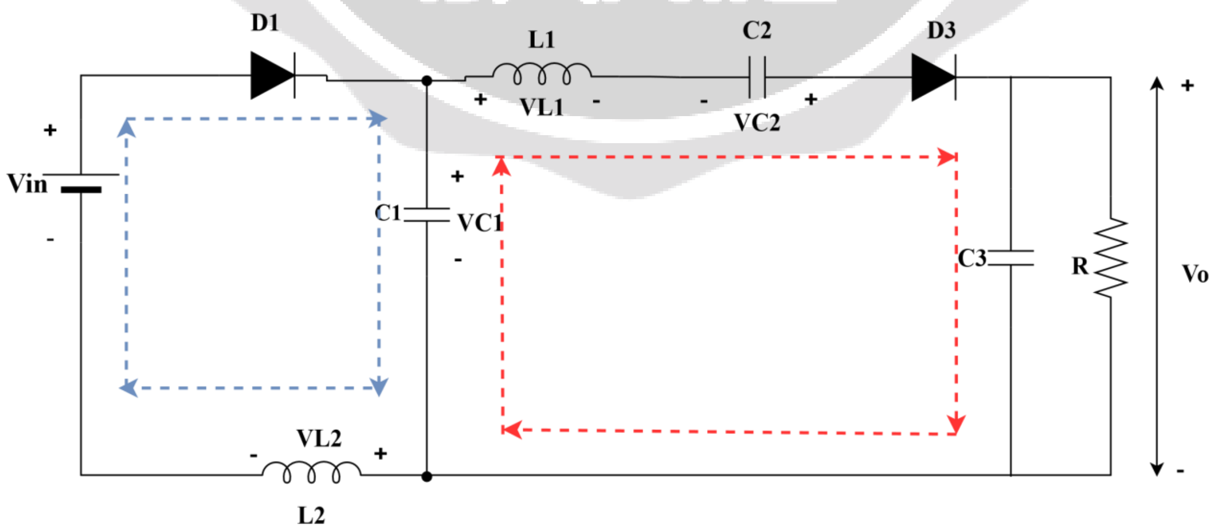


Fig 5. Equivalent circuit for switch-off mode of operation

B. DISCONTINUOUS CONDUCTION MODE:

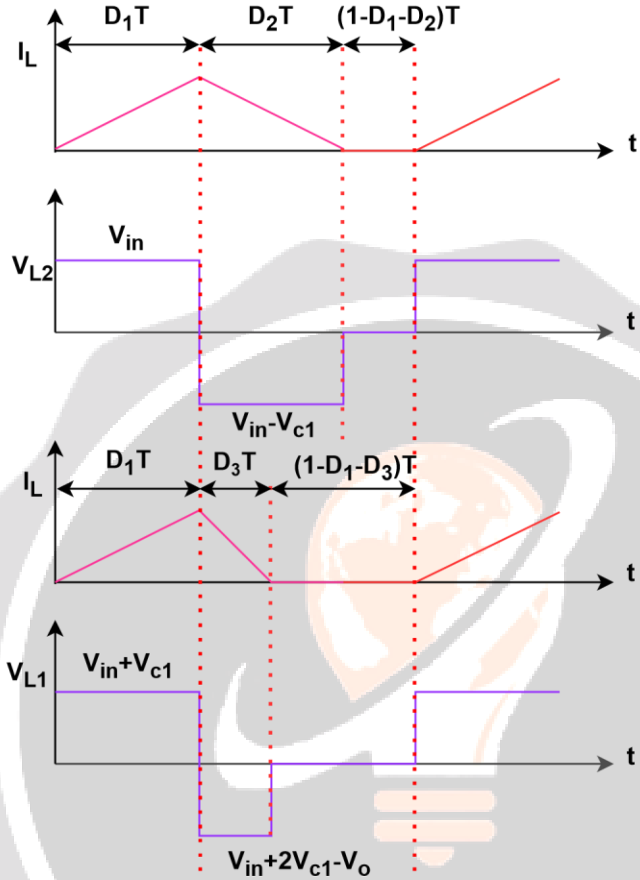


Fig 6. Equivalent circuit for switch-off mode of operation.

Figure 6 illustrates two conditions for a discontinuous conduction mode. Any discontinuity in any one of the inductor currents causes the converter to switch to discontinuous conduction mode (DCM).

C. DESIGNING OF PASSIVE COMPONENTS:

This section explains how to design and calculate the passive components like inductors and capacitors for the converter. Getting the inductor and capacitor sizes right is key to making sure the converter works well in Continuous Conduction Mode (CCM). The size of these components depends on factors like the switching frequency, output load, and duty cycle. Higher switching frequencies generally mean you can use smaller components.

1. **Choosing the Right Inductor Size:**
   The main goal when designing the inductor is to make sure the converter operates smoothly in CCM.
2. **Selecting the Capacitor Size:**
   When picking a capacitor, you need to consider how much voltage ripple is allowed and the voltage that will be applied across the capacitor. You need to choose a capacitor that’s strong enough to handle the high voltage without getting damaged or bursting.

D. Real Voltage Gain:

Some hidden factors, like the resistance of the switches, diodes, and the equivalent series resistance (ESR) of inductors and capacitors, can really affect the efficiency. Figure 7 shows the difference between the ideal gain and the real gain for the proposed converter design.

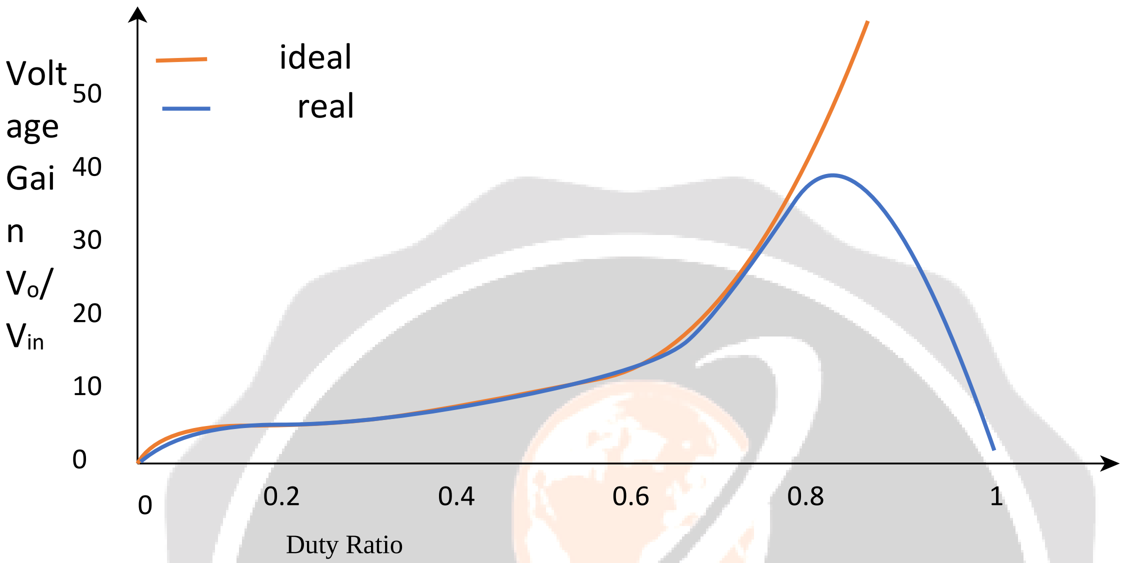


Fig 7. Ideal Vs real gain curve of a proposed topology.

IV. SIMULATION RESULTS :

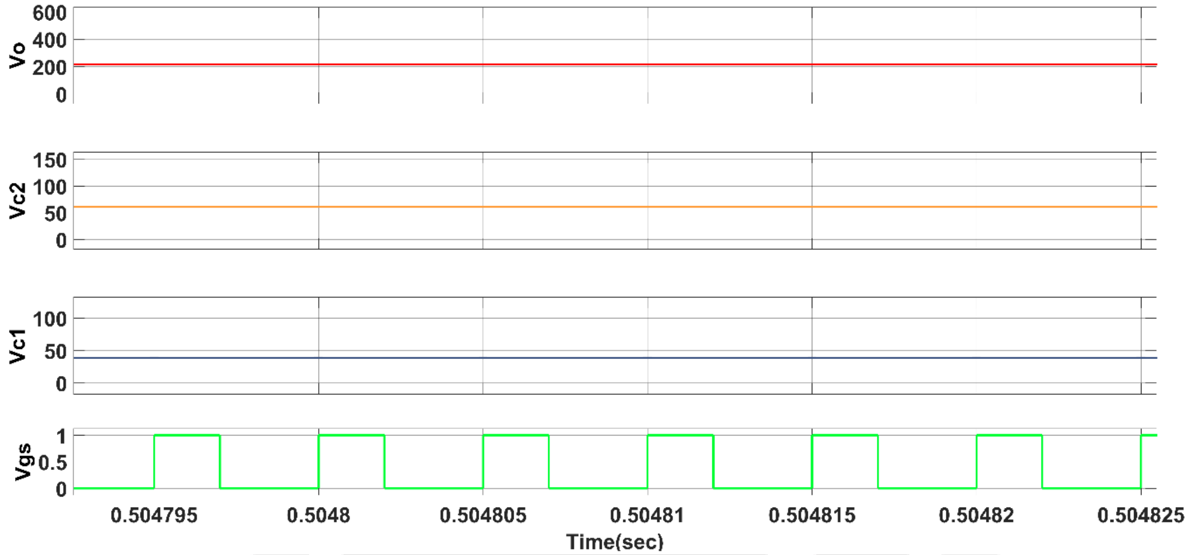
To evaluate the performance of a proposed high-gain boost converter the simulation results in open loop and closed loop were taken using MATLAB R2016a software.

OPEN-LOOP PERFORMANCE :

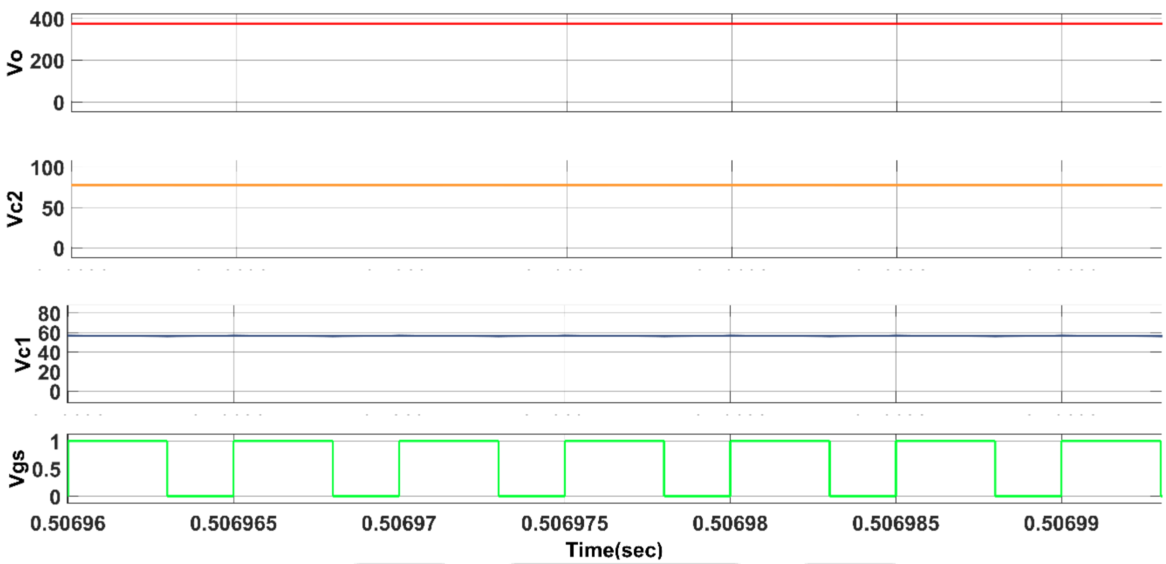
TABLE 2 shows a simulation designed parameters of a proposed converter. The simulation results of a proposed converter at different duty ratio values are discussed in this section.

Parameters	Specified Values
Input Voltage	V_{in}=24V~36V
R_L Load	R=500 Ω
Inductors L_1 & L_2	L1=24.5 μH,L2=1 mH
Frequency	200kHz
Capacitors C_1,C_2&C_3	C1=33 μF,C2=220 μF,C3=220 μF
Duty Ratio	40%,60%,70%

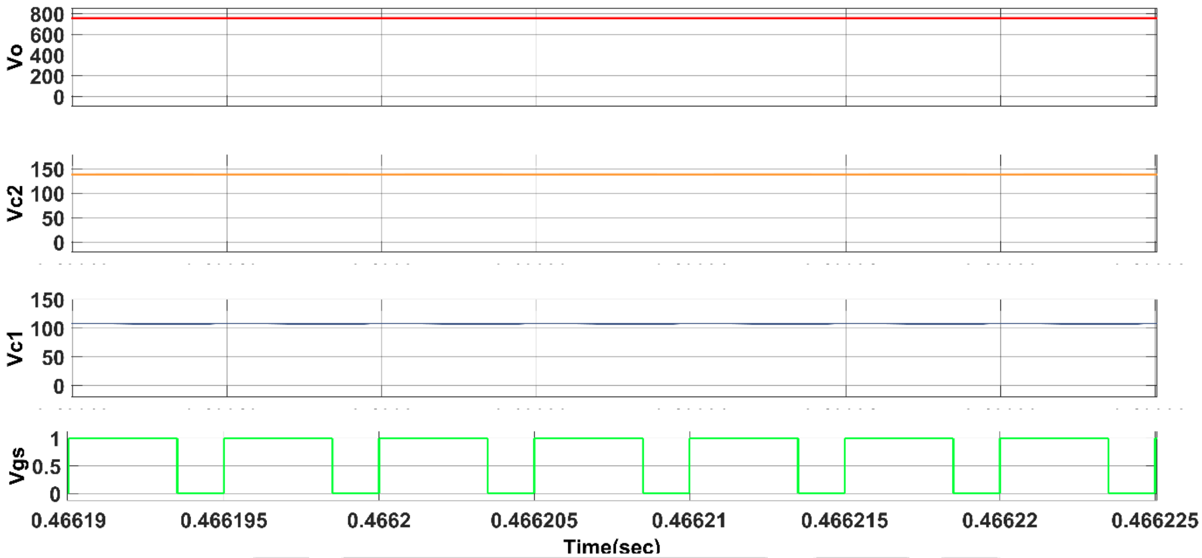
TABLE 2. Simulation design parameters.


600
400
200
0
Vo
150
100
50
0
Vc2
100
50
0
Vc1
1
0.5
0
Vgs
0.504795
0.5048
0.504805
0.50481
0.504815
0.50482
0.504825
Time(sec)

(a)


400
200
0
Vo
100
50
0
Vc2
80
60
40
20
0
Vc1
1
0.5
0
Vgs
0.50696
0.506965
0.50697
0.506975
0.50698
0.506985
0.50699
Time(sec)

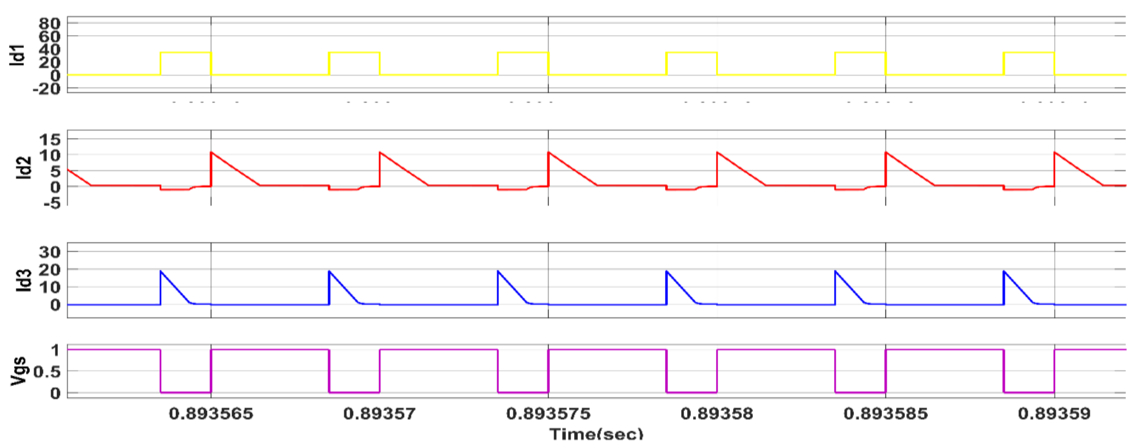
(b)



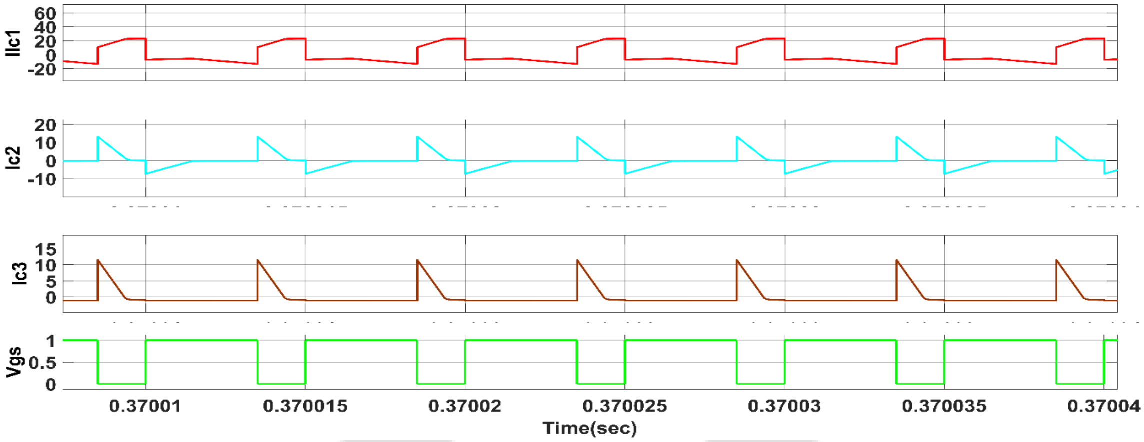
(c)

Figure 8: simulation waveforms (v_o,v_{c1},v_{c2} & v_{gs}) of a proposed converter at duty ratio of 0.4,0.6 &0.7 respectively

Figure 8 (a) shows the simulation result of the proposed converter at 24 V input. The duty ratio is set at 0.4 with a load resistance of 500 ohms. The measured output voltage is determined to be 216 V. Furthermore, the voltage of across capacitors ($C1$ and $C2$) is measured to be 39 V and 61 V respectively. Figure 10(b) shows a simulation outcome at a duty ratio of 0.6 with the same load resistance and input voltage. The measured output voltage is determined to be 375 V .



(a)



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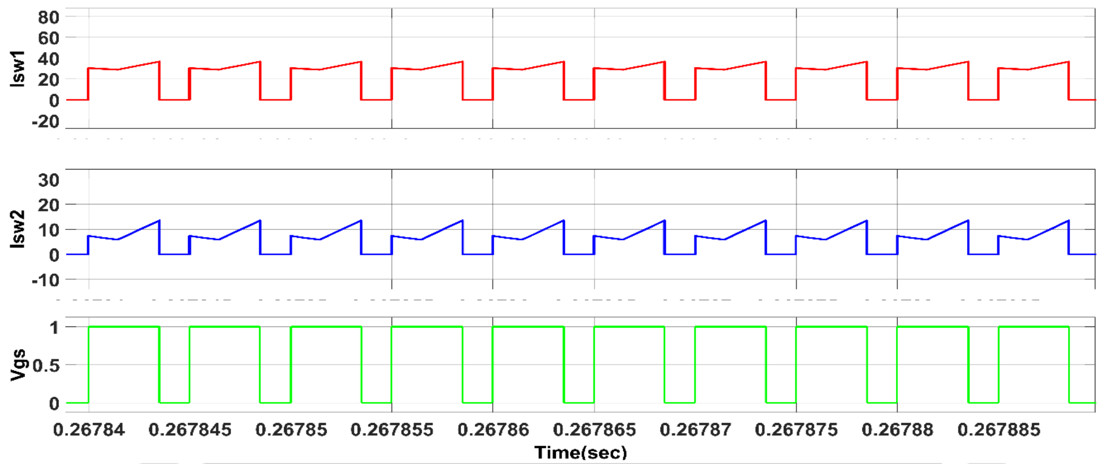

(c)

Figure 9:current waveforms of diodes, capacitors and switch respectively

Subsequently, the voltages across capacitors (*C*1 and *C*2) are found to be 57 V and 77 V respectively. Figure 10 (c) shows the simulation outcome at 36 V input. The duty ratio is set at 0.7 with a load resistance of 500 ohms. The measured output voltage is determined to be 755 V. The measured capacitor voltage (*C*1) is approximately 110 V, while capacitor (*C*2) has a voltage of 138 V respectively. Figure 9 (a) shows the simulation result of capacitor current waveform (*C*1,*C*2, and *C*3). The diode current (*ID*1, *ID*2, and *ID*3) and switch current (*ISW*1, and *ISW*2) simulation waveforms are shown in Figure 11 (b) and Figure 11 (c) respectively.

CONCLUSION:

We've developed a new high-gain boost converter specifically designed for renewable energy systems. After testing and analysing it, we found that the converter can increase the voltage by more than 12 times with a duty cycle of 0.6. Unlike other designs, this converter doesn't use a coupled inductor, which helps reduce electromagnetic interference, lowers energy losses, and makes the converter lighter. The design is simple and highly efficient, with an efficiency of around 94.5% when the input voltage is 24V. These features make it a great option for a wide range of medium to high-power applications.

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