High Gain Non-isolated DC-DC Converter Topologies for Energy Conversion Systems

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Abstract

For the accurate conversion and conditioning of energy in low voltage level applications powered by photovoltaics, batteries, and fuel cells, static power converters are required. This is necessary in order to satisfy the standards that have been set forth by the load system. Applications such as grid-connected inverters, uninterruptible power supply (UPS), and electric vehicles (EV) are examples of uses that place a premium on the efficiency and static gain of a power converter. In theory, the most fundamental nonisolated topologies for voltage step-up are the regular boost and buck-boost converters. Buck-boost converters are sometimes known as dual boost converters. Combining the functions of boost converters and buck converters results in the creation of buckboost converters. In order for these converters to achieve high voltage gain, they usually need to operate at extremely high duty ratios. During this time, the converters suffer large power losses due to the output diode's capacity to execute reverse recovery. Within the scope of this thesis are discussions of novel high stepup topologies with coupled inductors and voltage gain extension cells. In addition, the study of these topologies, together with the design challenges and methodology that were used to develop them, is described here. It is feasible to achieve a large improvement in performance by contrasting the first solution that was provided with the most recent state-ofthe-art topologies that were presented. We propose two different topologies, each of which makes use of connected inductors in addition to voltage gain extension cells. Both of these topologies are presented below. Clamp circuits are frequently required for power converters that use linked inductors as a method for managing the switch voltage excursion. Clamp circuits help prevent the switch voltage from going outside of its normal range. To begin, it is suggested that a step-up converter be selected that is basic, has a cheap cost, and is capable of active as well as passive clamping. Comparisons of the performances of the two different kinds of clamp circuits reveal that the active clamp solution is capable of achieving a greater degree of efficiency than the passive clamp solution. According to the information that is supplied in point two, the most significant downside of increasing the power level of a linked inductorbased converter is the enormous current ripple that is created by the operation of the connected inductor. DCDC converters are often spaced apart in a manner that allows for a variety of distances between them. This allows for the input current to be dispersed uniformly, for the current ripple to be reduced, and for the power density to be raised. This thesis presents a high static gain input parallel output series converter that combines linked inductors, switches the power flow equations, and switches the direction of the power flow. All of these

functions are accomplished by switching the direction of the power flow. A closed loop controller that was developed with the assistance of dynamic analysis can be used in order to regulate the output voltage of an interleaved converter. This can be done in a number of different ways. The modelling and experimental data from the high step-up converter designs of the lab prototypes are presented here along with a description of the design process. the results of tests carried out on prototypes of a converter with a single phase output of 250 W and an interleaved output of 500 W;

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Chapter 1

1.1 Introduction

In recent years, there has been a surge in interest in using renewable energy sources, which has led to an increase in the significance of energy conversion systems. This gain in significance is due to the fact that energy conversion systems are able to convert one kind of energy into another. These systems require components for power conversion that are dependable and effective if they are going to be capable of transforming one form of energy into another. High-gain, non-isolated DC-DC converters are the fundamental components of these systems and the important figures in the process of energy conversion that takes place within them. High-gain, non-isolated DC-DC converters are able to turn one DC voltage into another with a different magnitude, regardless of whether the magnitude is more or smaller than the first DC voltage. This is possible since an isolation transformer is not required for this process. Due to the high voltage conversion ratio that they offer, these converters are helpful for a wide number of applications. Some examples of these applications include fuel cells, solar systems, and battery energy storage systems. Additionally, they find widespread application in a wide variety of other industries, such as the automotive company, the aviation industry, and the telecommunications industry, to name a few of those industries. High gain non-isolated DC-DC converters can be difficult to design and install for a number of reasons, including component stress, electromagnetic interference (EMI), electromagnetic compatibility (EMC), and control complexity, to name just a few. Because of these issues, the level of reliability can get worse, and the operation might become less efficient while also costing more money. In order to get around these issues and boost the performance of high gain non-isolated DCDC converters, it is absolutely necessary to come up with creative and original solutions. In order to achieve this goal, we will have to devise strategies that are original and imaginative. The purpose of this study is to analyse and evaluate a number of possible high-gain, non-isolated DC-DC converter topologies that can be utilised for energy conversion system applications. The development of innovative solutions to the difficulties that are connected with the manufacturing and application of these converters is the objective of this research. The major focuses of this study's research topics will be the theoretical analysis, prototype design and implementation, and experimental evaluation of a few distinct topologies for high-gain, non-isolated DC-DC converters. These aspects of the research will be carried out in order. The initial stage in this research project would be to do a literature search on high-gain, non-isolated DC-DC converters and then summarise what was learned about such converters' topologies, control systems, and applications. The other parts of the research that need to be done will build upon the foundation provided by the findings of the literature review. After conducting a review of the pertinent literature, the study will go on to the design and analysis of topologies for high gain non-isolated DC-DC converters. This will take place after the review of the relevant material. During the time period of design and analysis, simulation tools will be used to construct several converter topologies and evaluate how well they work. The efficiency, power density, and overall cost of the converters will be considered in the analysis of their performance. After determining the best high gain nonisolated DCDC converter architecture, the investigation will then move on to the stage of developing and testing a prototype. This will happen after a decision has been made regarding the optimal architecture. After the topology has been decided upon, the prototype will be created and constructed with that topology, and then it will undergo experimental testing to determine how well it functions. The efficiency of the prototype will be evaluated in relation to the existing state-of-the-art alternatives, and the implications of the study's findings will be discussed in terms of the various uses that might be found for its findings. The study will help in the development of efficient and cost-effective energy conversion systems by shedding light on the design and implementation of high gain nonisolated DCDC converters. This will be accomplished by illuminating the design and application of these converters. The purpose of this research is to investigate and assess several alternative topologies for highgain, nonisolated DC-DC converters that are used in energy conversion systems. The purpose of this research is to propose original answers to problems that have been encountered during the manufacturing and implementation of these converters, as well as methods that may be used to enhance the efficiency of energy conversion systems. The findings of the study will provide information that may be used in the creation of energy conversion technologies that are efficient, effective, and highperforming. During the stage where the power is being converted, many eco-friendly methods of power supply need the use of a DC-DC converter that has a high efficiency and a high step-up. High intensity discharge (HID) lights, electric cars, gridconnected inverters, motor drives, uninterruptible power supply (UPS) systems, telecommunication/network server power systems, and distributed power generation (DPG) systems are examples of common applications for this technology. In addition, high voltage step-up gains of approximately 10 times or greater become more significant when the system is fueled by low voltage energy sources such as Li-ion batteries, solar panels, and fuel cells. These low voltage energy sources are characterized by their low voltage output.

In many applications, a DC voltage that is sufficiently high and stable is required or is considered normal. In addition, the high overall cost of a renewable energy system makes it imperative to include power electronic converters that have a high efficiency rating.

The simplest non-isolation topologies are boost and buck-boost converters, and only these converters can produce output voltages greater than source voltages [13, 14]. These converters are the most common types of non-isolation topologies. The bulk of boost and buck-boost converters must, however, run at extremely high duty ratios in order to obtain a significant voltage rise (more particularly, a 10 times increase). As a result of the two output diodes continuing to operate in this configuration, current pulses with a large amplitude, brief duration, and significant reverse recovery losses will continue to be maintained. In order to be compliant with the voltage rating of the semiconductor switching devices, the output voltage must also be increased. Additionally, when the duty ratio is large, the conduction losses of the semiconductor device may have a bigger impact on the system's performance. [14] It's feasible that the efficiency will drop to zero as the output voltage, duty ratio, and efficiency all get closer to being zero. Because of this, it's possible that the converter won't respond dynamically to changes in the system's characteristics or potential variations in load. This behaviour is frequently seen when a converter exhibits boost or buck-boost functionality. Avoiding overly high duty ratios is the challenge when employing a high stepup DC-DC converter.

1.2 Objective

The inquiry and assessment that are the primary focuses of this report are the many different high-gain, non-isolated DC-DC converter topologies that can be used in energy conversion systems. The primary goals of this research are to investigate the characteristics of existing high gain non-isolated DC-DC converter topologies, to compare and evaluate the efficacy of various high gain non-isolated DC-DC converter topologies in terms of efficiency, power density, and cost, and to develop a new high gain non-isolated DC-DC converter topology that can improve the performance of energy converters. In this project, we will investigate the difficulties that designers and engineers encounter when attempting to create and make use of high gain nonisolated DC-DC converters. Component stress, electromagnetic interference and electromagnetic coupling, and control complexity are some of the problems that can arise.

The purpose of this study is to investigate and assess the efficacy of a number of different converter topologies so that fresh solutions may be developed for these problems and the efficiency of energy conversion systems can be increased. The primary objective of this paper is to encourage the development of energy conversion technologies by offering recommendations and an analysis for the design of high-gain, non-isolated DCDC converter topologies. These topologies have the potential to enhance the effectiveness and availability of energy conversion technologies. In order to accomplish this objective, it will be required to conduct an in-depth examination of the multiple high-gain non-isolated DC-DC converter topologies that are now available. Furthermore, it will be necessary to design and test a novel topology that is capable of providing superior performance in terms of efficiency, power density, and cost. The long-term goal of this research is to contribute to the development of energy conversion systems that are high-efficiency as well as costeffective. This research will assist in making energy conversion systems more effective, less expensive, and more efficient, all of which have the potential to have a substantial influence on the economy as well as the environment. In order to attain this goal, information on the creation of high gain non-isolated DC-DC converters will be provided.

1.3 Literature review

Our group looked through the available research on "High Gain Non-isolated DC-DC Converter Topologies for Energy Conversion Systems" and came up with some noteworthy findings and new understandings as a result of this endeavor. Despite the fact that these converters often have low voltage conversion ratios and poor power densities, they are widely utilized in power electronics. This is the case despite the fact that these converters are not isolated from one another. As a direct consequence of this, high gain nonisolated DC–DC converter topologies have been developed. These topologies are capable of delivering an improved power density and voltage conversion ratio. We came to the conclusion that a few modified boost converter topologies, such as the interleaved boost converter and the softswitched boost converter, are able to increase converter performance. This is accomplished by lowering the voltage stress placed on the switching devices, boosting efficiency, and cutting down on electromagnetic interference (EMI). In addition, we discovered that the boost converter architecture places less voltage stress on the capacitors and inductors than the cuk converter design does, yet the cuk converter topology still manages to provide a satisfactory amount of power density. We have discovered that a number of different modified cuk converter topologies, such as the interleaved cuk converter and the hybrid cuk converter, are able to increase the performance of the cuk converter. This is accomplished by lowering the voltage stress placed on the capacitors and inductors, increasing the efficiency, and lowering the electromagnetic interference (EMI). In addition to other high gain non-isolated DC-DC converter topologies, the flyback converter, pushpull converter, and half-bridge converter each have their own set of benefits and drawbacks. Whether or not these topologies are suitable for a particular application is determined by a number of criteria, including the input and output voltage range, the power level, and the cost. When compared to traditional nonisolated DC-DC converters, high gain non-isolated DCDC converter topologies were discovered to be capable of providing significant gains in voltage conversion ratio and power density. However, selecting the optimal topology calls for thorough research and deliberation, and it is ultimately determined by the requirements of the particular application. In the next part, an evaluation and analysis of the overall performance of a variety of high gain nonisolated DC-DC converter topologies will be carried out, focusing on cost, power density, and efficiency.

Chapter 2 : Overview

2.1 High Step-up DC-DC Converters in a Variety of Applications

The power conversion stage of many applications that are powered by RES requires a DCDC converter that has a high efficiency and a high step-up. The following items are examples of common examples: uninterruptible power supply (UPS) systems [6, 7], highintensity discharge (HID) bulbs [10], electric motors [17], and grid-connected inverters [14]. Following is a section that provides a quick overview of a few emerging applications for high step-up DC-DC power converters.

an inverter for solar power that is connected to the grid 2.1

The generation of electricity is one of the most important applications for solar photovoltaic (PV) technology, particularly in nations with an abundance of solar radiation. This is especially true in countries where there is a lot of sunshine. The program can operate independently or as a component of a system that is connected to a grid. The market for photovoltaic power systems that are connected to the grid is expanding at a rapid rate in Europe, with record additions of 1.9 GW in Germany, 2.4 GW in the United Kingdom, and 0.9 GW and 0.4 GW, respectively, in France and Italy in 2014 [18]. In the same year under consideration, Japan, China, and the United States each added 9.7, 10.6, and 6.2 GW of new capacity, respectively. There are currently 177 GW of capacity that has been deployed all around the world [18].

The block diagram of a typical photovoltaic power system that is connected to the grid is shown in Figure 2.1.

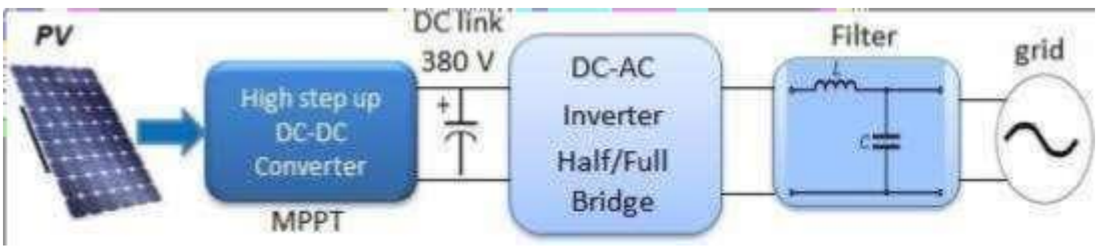


Figure 2.1 Single phase grid connected renewable energy system

are usually linked in series to acquire the DC link voltage and power converter required to meet the PV's maximum power point (MPP) range. This is done so that the DC link voltage and power converter may be obtained. On the other hand, if there is partial shadowing or a mismatch, the MPP losses will escalate dramatically. An alternate setup places a built-in direct current to direct current converter in the module of each solar panel. The system's MPPT efficiency rises and costs are decreased as a result. Each panel is isolated from the others in order to maximise the system's power and provide flexibility. The topology, on the other hand, frequently makes use of two power electronic converters. In order to generate the line voltage for alternating current, which is typically between 380 and 400 V DC, the comparatively low DC voltage from the solar panels must first be increased to a sufficient level by a high stepup boost converter. These voltage levels are usual. The grid receives sinusoidal current from the DC-AC inverter, which is the second kind of converter. The DC bus voltage level is stabilized and the PV array is used to its fullest extent thanks to the maximum power point tracking (MPPT) algorithm and the highest step-up DC-DC converter. The high step-up DCDC converter's performance is crucial to the overall performance of the

PV system since it is the key component that connects the solar photovoltaic with the DCAC inverter and controls the power flow. Due to the limited availability of solar energy, which only occurs during the day, a power system that is connected to the grid may only be able to supply power for a portion of each day. The main disadvantage of having a gridconnected electricity system is this. As a fix for this problem, energy storage systems (ESS), such batteries, are typically incorporated into solar inverter systems [19]. In addition to ensuring that supplies are constantly accessible, this serves to improve the system's overall performance. Utilising the ESS is meant to give the DC bus a backup system that will power it when the sun isn't shining while simultaneously transferring solar energy to it when it is. The ESS will send solar energy to the DC bus when the sun is out. The grid might then get dependable, quick-acting alternating current (AC) electricity as a result. A bidirectional DCDC converter can be used to combine the ESS with the gridconnected PV system. Power can move in both directions (boost and buck) thanks to this form of converter, which also makes it easier for it to do so.

2.1.1 High Intensity Discharg (HID) Lamp

For usage in vehicle headlamps, high-intensity discharge (HID) lamps offer numerous advantages over normal halogen bulbs, including improved performance, longer life, better light beam focus, and superior color rendering capabilities. normal halogen bulbs are the more common type of light bulb.

In steady state operation, the performance of HID lamps is comparable to that of ordinary discharge lamps, in spite of the fact that HID lamps have a number of benefits. In this context, the utilization of a ballast is essential for controlling the power of the bulb.

Figure 1.2 is an illustration of a typical ballast circuit, which powers and illuminates the light by utilizing a high step-up DC-DC converter, an inverter, and an igniter. This circuit can be found in most modern ballasts. The HID is powered by the 12-volt battery seen in automobiles; however, the input voltage of the battery is significantly lower than the working voltage of the ballast. The ballast is necessary to make use of a high step-up DC-DC converter in order to get the voltage of the battery up to between 380 and 400 volts (V) during startup and during steady state operation in the range of (60- 135 V) [10, 11]. As a consequence of this, in order for the light to function, a high-step-up DCDC converter that has a voltage gain of approximately ten times is necessary.

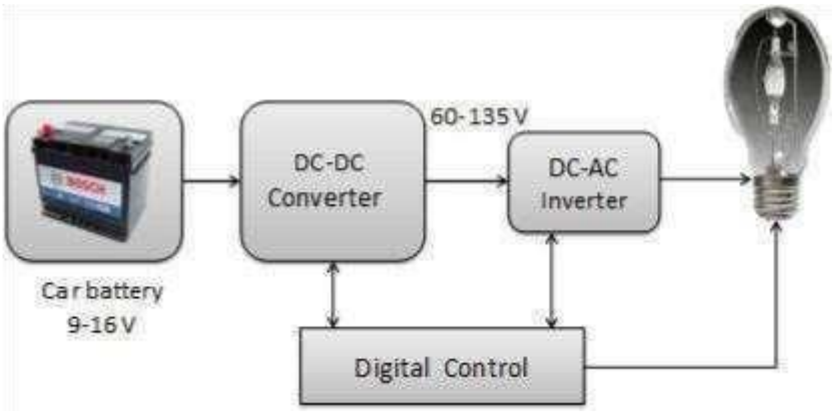


Figure 2.2 High Intensity discharge lamp ballast block diagram

2.1.2 Automotive Electric

The automotive industry is putting a lot of emphasis on electric cars (EV), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), and fuel cell vehicles in order to satisfy the demand for emission-free automobiles that also offer improvements in fuel efficiency, comfort, and safety. However, the efficiency, cost, and size of the power electronic converter and machine are the primary concerns that need to be addressed. in particular, the DC-DC converter that features a high step-up ratio and is utilized to link the voltage of the battery packs to the voltage of the fuel cell.

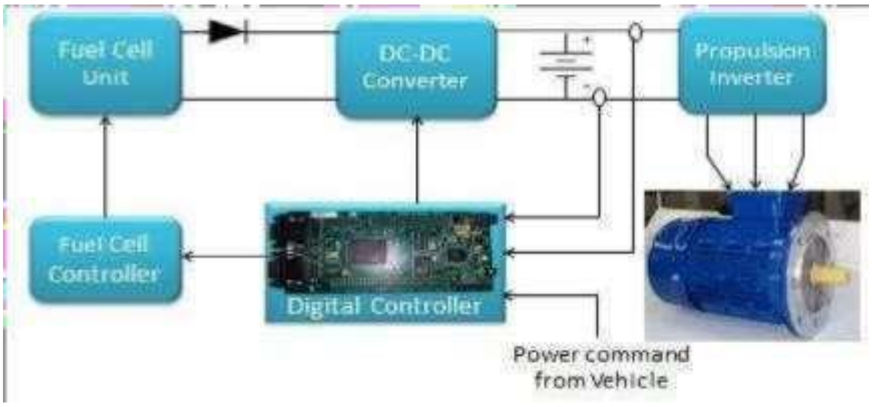


Figure 2.3 Electric vehicle drive train

The example of the propulsion system for a fuel cell vehicle that may be found in figure 2.3. The relatively low DC voltage of the fuel cell is usually raised to a standard DC link voltage of 400V using a high step-up DC-DC boost converter. This voltage is compatible with the battery and is also suitable for use with the fuel cell. After then, power is supplied to the propulsion motor by means of an inverter. For instance, lithium-ion batteries are frequently utilized as a supplemental power source in motor vehicles during the starting, accelerating, and hill climbing processes. [9] provides a listing of a wide variety of configurations and categories for the propulsion systems of electric vehicles. [20] illustrates how an electric vehicle can transmit power in either direction using an energy storage system (ESS) and a bidirectional direct current to direct current converter. The regenerative energy that is produced by electric equipment that fails is transferred back into the battery. As a result of the converter increasing the capacitive energy supply, the vehicle is able to start and accelerate with increased velocity.

2.1.3 Power Supply Uninterruptible PSU

Uninterruptible power supplies, also known as UPS, are used extensively to power sensitive loads and safeguard them during mains outages in both typical and unusual scenarios involving utility power [6, 7]. A variety of critical loads, including servers, computers, communication systems, and medical equipment, have seen widespread adoption of the use of uninterruptible power supplies (UPSs). In order to link a wide variety of sources and loads, every UPS makes use of specialized DCDC power electronics converters. For example, the power factor correction (PFC) circuit converts the ac-line voltage, which is 90– 265 Vrms, into the regulated DC link voltage, which is 380–400 V, that the inverter needs. This circuit is an element in the overall architecture of the UPS. In the event that there is a disruption in utility service or a power blackout, the UPS will switch to backup mode and begin producing the AC output of the 48 V backup batteries in order to lighten the load. To bring the voltage of the battery bank up to the level required by the DC bus, a high-step-up converter is going to have to be used.

2.1.4 Power System for Telecommunication

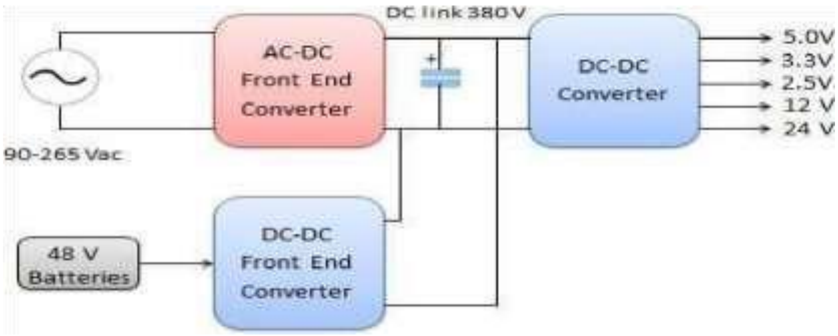


Figure 2.4 Dual front end telecom power system

The amount of reserve time that UPS systems typically supply is far lower than the amount of time that is required for communications power systems, which can be as much as 30 minutes. Therefore, using a telecom bus that operates at 48 volts direct current (DC) to supply power to devices that are utilized for data processing in a telecom environment has become conventional [10]. Figure 2.4 displays an

example of a power supply system for telecom equipment.

The power supply is equipped with a number of stages, which contribute to its great efficiency as well as its high power density [8]. An AC-DC system is widely utilized because it is capable of producing a high step-up DC bus voltage from an AC-line voltage (90 to 265 Vrms), which is necessary for the first stage. In order to bring the harmonic level down, the AC-DC converter acts as a circuit that may be adjusted to change the power factor. The logic circuits have their bus voltage reduced from the standard 380 V to a more manageable value of 5, 3.3, 12, and 24 V, respectively. This reduction is strictly monitored. However, when the mains power fails, the telecommunications business switches to using 48V.

The most common type of backup system is a bank of DC batteries. In this scenario, a

DCDC high step-up back-up converter is required in order to boost the voltage of the 48 V DC battery bank to the 400 V DC connection voltage in a way that is both speedy and efficient. For the power supply system for the communications server, it is important to have a high step-up DC-DC converter. This converter must be able to generate 400 V DC from 48 V DC batteries.

2.1.5 Independent Power System

Because of their capacity to generate and deliver electricity to a diverse set of demands, distributed power generation (DPG) systems are increasingly being recognised as crucial building blocks for the power grids of the future. DPG utilises microgrids in conjunction with renewable energy sources such as batteries, solar panels, fuel cells, and loads in order to achieve the aims of trustworthy control, monitoring, power quality enhancement, fault detection/isolation, and stabilisation [12]. Microgrids are capable of operating independently. The distributed power generation (DPG) model, or the gridlinked model, depending on the configurations, is without a doubt the foundation of a smart grid. Figure 2.5 is a diagram that depicts the DPG in the form of a block diagram. Before the system can connect to the utility grid and/or provide supplemental power to consumer loads, it requires specialised power converters that are able to convert and regulate the power that is generated [21, 22]. In order to satisfy the requirements of a wide variety of local loads with electricity that was generated locally, it is necessary to deploy a variety of DC-DC converters that operate at variable power levels. In a nutshell, the quality of the whole system and its level of efficiency are contingent on the level of performance exhibited by these power electronic converters.

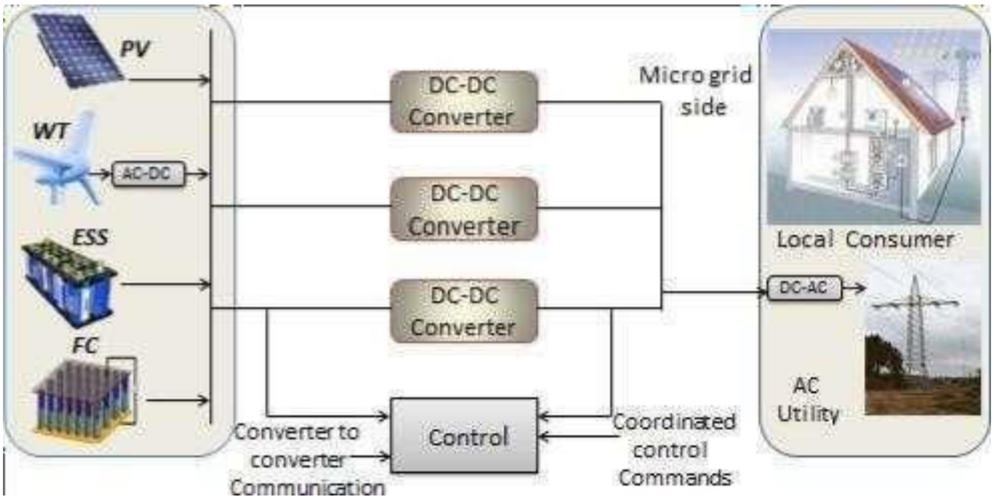


Figure 2.5 Distributed power system

2.2 High-step-up converter qualities

The performance of high step-up DC-DC converters is typically characterised by both high output voltage and high input current as the standard. The high input current can be traced back to the low input voltage. Therefore, some of the desirable properties of high step-up converters will be briefly covered in the parts that are to come after this one.

2.2.1 A High Level of Conversion

steep step-up DC-DC converters are necessary for a wide variety of applications that are powered by RES or ESS. For instance, the output voltage level of the PV array in the grid connected inverter is typically low, ranging from 16 to 43 volts, whereas the DC bus voltage required for synthesising the

AC line voltage is 380 to 400 volts DC. In order for the system to operate in a steady state, the array voltage must undergo a voltage gain of at least ten times (10X) that of the DC link voltage.

2.2.2 High-Efficiency

The high step-up DC-DC converters' overall efficiency suffers as a direct result of the huge influence that the enormous input current has. The input current is magnified when the input voltage is reduced. As a result, the increased peak and root-mean-square (RMS) current stress placed on the switching components constitutes a considerable obstacle to the improvement of efficiency. In order to cut down on conduction loss and improve the efficiency of DC-DC converters, low-rated components that have a low on-state resistance are given preference. Another issue that arises in contexts involving high voltage is one involving the output diode's potential for reverse recovery.

Diodes with lower ratings often recover faster than higher-rated ones.

2.2.3 Low Current/Voltage Ripple

Both the current and the voltage are subject to variations as a result of the inherent switching feature of power electronic converters. In a DC-DC boost converter, for instance, the power MOSFET or IGBT switches, which results in the current flowing through the inductor producing a triangle waveform with a DC offset. The DC component of the current being carried by this inductor travels through the load as well as the AC components. The output capacitor then cuts across both of these. The time-varying current that flows through a capacitor leads to the generation of a ripple voltage in the capacitor. Above and above the value attained during the steady state, there is some oscillation in either the input current or the output voltage. Those who work on the development of power electronic converters believe that the magnitude of the ripple is an important factor. It is imperative that the performance of the converter be optimised in order to reduce the current/voltage ripple of the AC component, which brings the efficiency of the system down. In an ideal world, the output would only consist of direct current (DC) components.

2.2.4 Immediate Response

In a closed loop control system, the duty ratio is determined by using the nominal operating point of the DC-DC converter. This allows for the dynamics of the converter to be utilised. The DC load requirements are the foundation for this feature, just like load resistance is the foundation for this characteristic. Both the load resistance and the duty ratio are exogenous properties that need to be modified because of the instability of the pole-zero. The converter needs to be able to function normally despite the challenging nature of the surrounding environment and should be able to respond rapidly to varying levels of supply or load.

Chapter 3 Methodology

3.1 Topology Evaluation for High step-up DC-DC Boost Converter

The severe PWM duty ratio, the conduction losses that come from high rated power devices, and the reverse recovery-related loss of the output diode are the primary challenges that must be overcome in order to improve the efficiency of fundamental DC-DC converters

such as boost and buck-boost in high step-up applications. Numerous research have been conducted to investigate various topologies that may be able to overcome the constraints of fundamental topologies, such as static gain, power device voltage stress, power density, and efficiency. These limitations have been identified as areas that might be improved upon. The next section will concentrate primarily on conducting research into the positive and negative aspects of a variety of topologies.

3.1.1 Cascade Converter

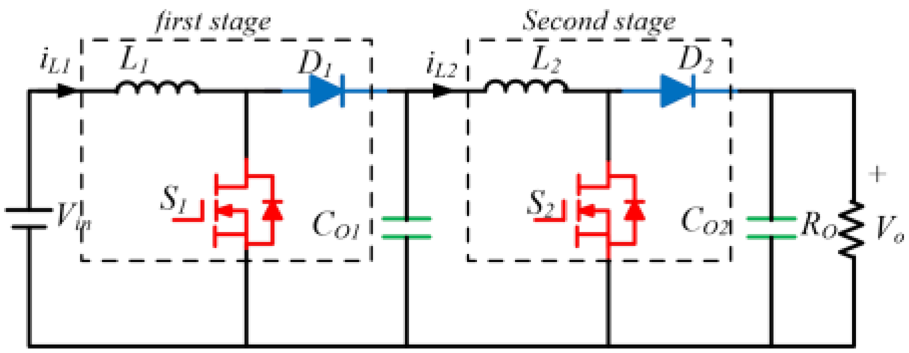


Figure 3.1 Cascade boost converter

Increasing the static voltage gain can be accomplished effectively by using two DC-DC boost converters connected in cascade [56]. As shown in Figure 3.1, forming an intermediate bus voltage around capacitor CO1 is mostly dependent on connecting the output stage of one boost converter to the input stage of another boost converter. A greater static gain is achieved as a direct consequence of the cascade structure's real-world production of an output voltage as a consequence of numerous boost stages. Because each stage in the cascade may perform step-up function without having to operate at an excessive duty ratio, the conduction and switching losses are greatly reduced when the cascade structure is utilised. The conduction loss of the first stage might be rather low, despite the huge input current that is being used. The current at the input of the subsequent stage isThe static voltage gain can be increased by employing two DC-DC boost converters in cascade in order to achieve this [56]. The decrease in conne voltage is the primary effect that the rise in voltage from the intermediate bus voltage has. In high power applications, the reverse recovery loss of the output diode might be rather considerable since the device voltage stress in the second stage is the same as the output voltage. The fact that the energy is changed twice certainly contributes to a drop in total efficiency, which is yet another significant disadvantage from the point of view of efficiency. Additionally, the combination of the various boost converter designs may result in instability in the system. The static voltage gain can be increased by employing two DC-DC boost converters in cascade in order to achieve this [56]. The decrease in conne voltage is the primary effect that the rise in voltage from the intermediate bus voltage has. In high power applications, the reverse recovery loss of the output diode might be rather considerable since the device voltage stress in the second stage is the same as the output voltage. The fact that the energy is changed twice certainly contributes to a drop in total efficiency, which is yet another significant disadvantage from the point of view of efficiency. Additionally, the interaction between the differentially designed boost converters might lead to instability in the cascade converter when seen from the perspective of a tiny signal [15].

Incorporating a passive or active snubber cell into the cascade converter to perform zerovoltage switching (ZVS) for active switches, as demonstrated in [36, 57], does not in the least improve the static gain of the initial architecture. In most cases, a continuous voltage load is applied to the device as a consequence of the original cascade structure. This is true even though the ZVS soft switching performance is excellent.

3.1.2 Converter of Quadratic Boost (QBC)

The problem of instability that was brought on by the cascade connection of two specifically built boost converters is addressed in [37, 39, 58] and is shown to have a straightforward solution that is provided by a quadratic converter. In order to create this converter, the switch S1 in Figure 3.1 is substituted for the diode D3 instead. As can be seen in Figure 3.2, the quadratic converter operates in the same manner as two normal boost converters that are connected in series and managed by a single switch. This analogy was chosen because it accurately describes how the quadratic converter works. The quadratic boost converter is able to function with a large conversion ratio and, as a result, does not require a high duty ratio. This is due to the fact that the total voltage gain is equal to the sum of the gains that are achieved by each of the multiple stages.

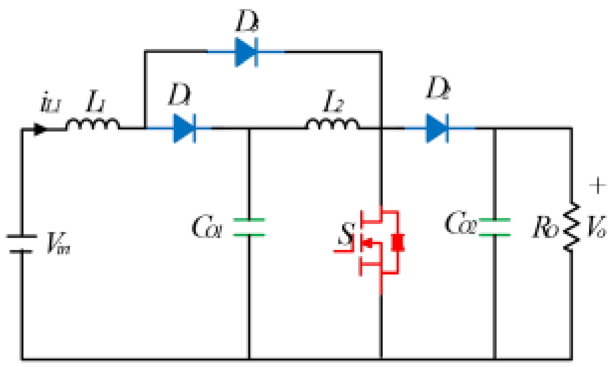


Figure 3.2 Quadratic boost converter

The fact that the quadratic boost converter, like the cascade converter, requires energy to be transmitted twice is the primary disadvantage of this type of converter. The converter necessitates the use of components with high ratings, which results in conduction losses. As a direct consequence of this, the voltage stress on the power switch and the output diode D2 is the same as the voltage that was generated. When dealing with high power, one of the most severe problems that can arise is reverse recovery of the output diode. The use of soft commutation in the power stage while making use of a quasi-resonant cell is detailed in [59].

3.1.3 Three-Level Boost Converter

The three level converter may be shown in Figure 3.3 [38, 60, 61], and the circuit has the benefit of voltage stress distribution among the power components. The device voltage stress is equal to one half of the total.

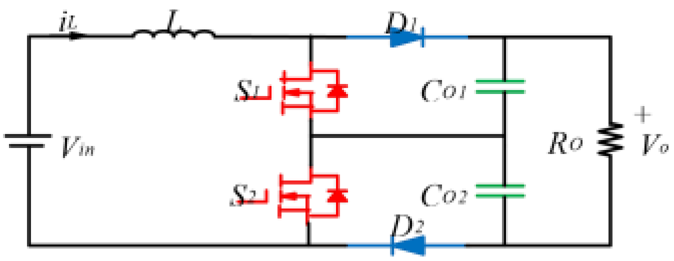


Figure 3.3 Three level boost converter

Resultant voltage from a converter. A further benefit of the design is that it makes it possible to significantly cut down on the overall volume of the inductor. It is more suitable for use in voltage step-up applications than the conventional boost converter is on account of these regular properties, which are typical of boost converters. on the hesitation shown by the state a little bit more specifically When there is little voltage stress across the device, conduction loss can be decreased by utilizing high performance MOSFETs. This is possible when there is also a decrease in the overall voltage. Switching loss and EMI noise are both greatly reduced as a direct result of the voltage that is applied across the device. Due to the fact that this architecture has the same amount of voltage gain as a regular boost converter, it is not possible to use it for many modern applications that require conversion ratios of 10 times or more. The most significant shortcoming of this topology is that it cannot be utilized in a variety of contexts and applications. In order for the converter to function properly, it is imperative that an unusually high duty ratio be maintained at all times.An additional difficulty arises from the fact that the diodes have a higher conversion ratio as well as reverse recovery losses. When dealing with high power, it is common for there to be a substantial amount of ripple current.

3.1.4 Voltage Multiplier Cell

Voltage multiplier cells are an alternate method that can be utilised to overcome the limitations of ordinary boost and buck-boost DC-DC converters [23]. These cells are useful for situations that require high performance and large conversion ratios. In order to get a high voltage gain in isolated DC-DC converters utilised in both low and high frequency travelling wave tube amplifiers (TWTA), voltage multipliers are utilised [62]. The voltage multiplier cell has been introduced into the design of the high voltage power transformers in order to assist with addressing difficulties relating to mass, volume, and losses. The layout of voltage multiplier cells shown in Figure 3.4 is their most fundamental form. The voltage multiplier cell generates an output voltage that is higher than the input voltage. This is accomplished through the utilisation of capacitor charge transfer, but it does so without the requirement of a magnetic component. It is possible to construct high step down or high step up converters by integrating the voltage multiplier cell into conventional converters such as buck, boost, and buck-boost [23]. The short story "The High Step"

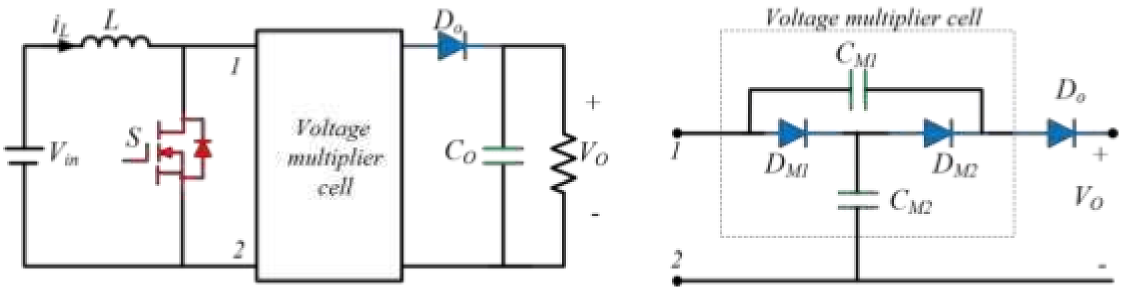


Figure 3.4 Boost converter with voltage multiplier cell

(a) Converter structure (b) voltage multiplier cell

Every fundamental topology results in the formation of a new structure that is similar to the original. It is important to note that there is no practical benefit to adding a voltage multiplier cell to a buck converter. This is something that should be kept in mind. When the power switch is turned on, the energy is stored in the input inductor. When the power switch is turned off, the energy is transferred to the output via the inductor through the capacitor known as CM1. As a direct consequence of this, CM1 and CM2 discharge sequentially towards the output. The number of voltage multiplier cells determines the amount of stress that is placed on the power switch voltage, and this stress decreases as the number of cells is increased. The maximum voltage stress that is applied to the power switch and the multiplier diodes is equal to fifty percent of the output voltage. To achieve a higher static gain, it is necessary to use a greater number of voltage multiplier cells.

3.1.5 Techniques for Switched Capacitor/Inductor

Traditional converters are able to generate a significant voltage gain by employing a method that is known as switched capacitor/switched inductor [40]. This is how they are able to accomplish this. By raising the amount of charge that is passed between capacitors and inductors, the approach raises the output voltage to a higher value. The generation of a steep function may be accomplished by combining conventional converters with a switching cell that is comprised of either two capacitors, two to three diodes, or two inductors, two to three diodes. In this case, step-up structures are the only ones that are taken into consideration; however, depending on the way the cells are clustered together, step-down structures may also be conceivable. If the primary switch of the converter is conducting, then the two inductors that are included within the switch inductor cell will either be charged in parallel or discharged in series. The behavior of the switch inductor cell is dictated by whether or not the primary switch is conducting. The primary switch of the converter will be turned off, which will result in either the two inductors being discharged in series or the two capacitors being charged simultaneously. Figure 3.5(a) depicts the switched capacitor converter, while Figure 3.5(b) illustrates the switched capacitor cell. Both of these components are illustrated in the images. An input voltage step-up function that is dependent on the transference of capacitor charge can be provided by the switched capacitor circuit when it is combined with a conventional boost or buck-boost circuit. This function is possible because the switched capacitor circuit has the capability of delivering an input voltage step-up function.

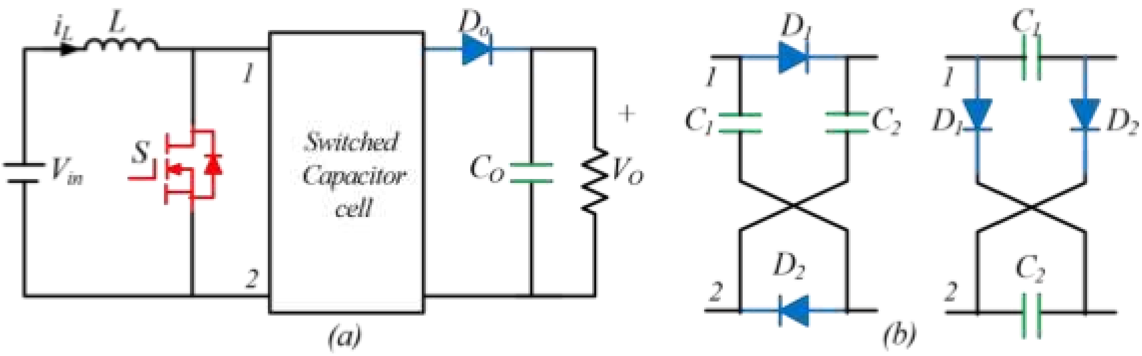


Figure 3.5 Switched capacitor structure

There are more converters now (a) thanks to converter structure (b) thanks to switched capacitor cell topologies [40, 63]. When the converter's switch is turned off, the switch cell's diodes conduct in the other way, enabling the input voltage from the converter to charge the switch cell's two capacitors in parallel. The capacitors discharge in series as the diodes reverse block when the switch is turned on. Using switched capacitor cells can result in both an increase in voltage gain and a decrease in device voltage stress [64]. Charge pumps, a popular switching capacitor circuit that is also used in DC-DC power conversion, have been used for managing integrated circuits for a very long time.switching causes the pulse currents. When there are more diode forward voltage dips in high step-up applications, the circuit becomes more difficult to understand and manipulate. Due to the high number of active devices and accompanying gate drives that are coupled with them, the converter can only be used in low power applications. This is because the increased cost and complexity of the converter is caused by these factors. In contrast to capacitors, the switched inductor cell [40] is made up of anywhere from one to three diodes and two inductors. Capacitors are not present. The switch inductor cell can also give a step-up of the input voltage when used in conjunction with regular converters to produce a one-of-a-kind power supply. These typical converters include boost, buck-boost, zeta, and sepic converters, among others. The physical layout of a boost converter that utilises a switched inductor cell is depicted in Figure

3.6(a). A switched inductor cell shown in its most common design can be seen in Figure 3.6(b). When the converter is finished,

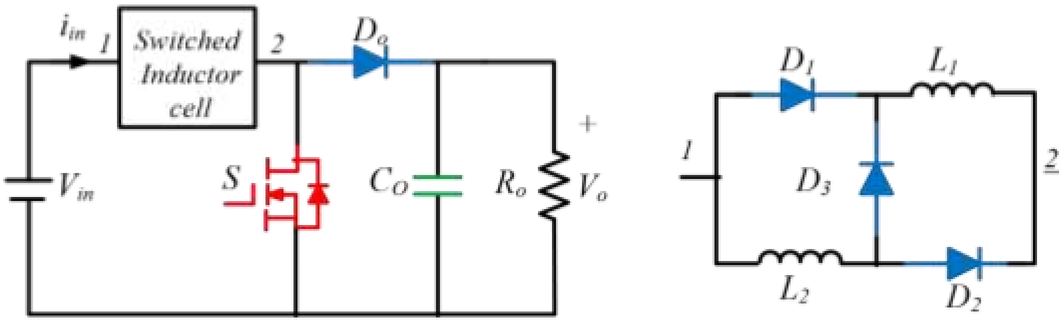


Figure 3.6 Switched inductor structure

(a) Converter structure (b) switched inductor cell

It is possible to improve the voltage gain by utilizing converters; but, without a larger duty ratio, static gains of 10 times or more will not be possible. Because the device voltage stress is the same as the converter output voltage, it can only be utilized in low power applications without suffering from major reverse recovery problems and dominant conduction losses. This is due to the fact that the output voltage of the converter is the same as the device voltage stress.

3.1.6 Voltage Lift Circuit

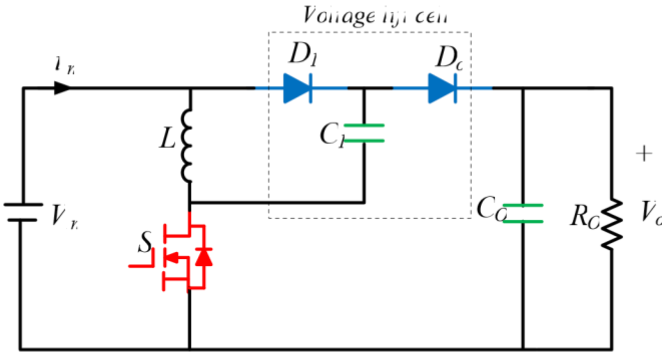


Figure 3.7: Voltage increase converter DC-DC converters that make use of the voltage lift approach have been able to successfully implement a variety of different high voltages and wide conversion ratios [41, 42, 67-69]. When applying the voltage lift approach [42], the output voltage of a DCDC converter will gradually grow along an arithmetic progression. The voltage raise cell that is typically utilised in boost converters is illustrated in Figure 3.7 for your perusal. Boost converters with a single voltage-raising cell are easier to design and require fewer components overall. To put it another way, when the switch on the converter is turned on, the input voltage charges the inductor and capacitor that are part of the voltage lift cell, and then both components discharge their respective amounts of stored energy in series to the output.

The primary shortcomings of the converter can be summed up as the fact that it has a lower static gain and a higher working duty ratio. Even while it is possible to combine a large number of lift circuits in order to boost static gain, it is always possible to greatly increase the number of passive components in order to increase voltage transfer gain. Regardless of whether or not it is feasible to integrate lift circuits, this is the current state of affairs. The difference between the input and output voltages is one way to characterize the switch voltage stress that is being applied. The distinction between the two is sometimes referred to simply as "the difference." Another method for gradually increasing the output voltage of a DC-DC converter is called super lift [41, 67]. This method can be utilized with either positive [41] or negative [67] polarity, depending on the particular application. In practice, the power series method is the one that is applied for calculating the voltage conversion ratio. [68]

Demonstrates how a voltage gain can be increased in accordance with a power law despite the fact that dividing a capacitor (or possibly an inductor) is required. According to the publication [69], similar findings demonstrate that switching the inductor for a switched inductor can boost the static gain in positive output super lift Luo converters. The ratio of line voltage to output voltage has increased by a factor of two as a consequence of this adjustment, which has an effect only at the highest duty cycle levels. The switch is designed to function at its full capacity and has a fast turn-off time. Furthermore, it has a high duty cycle. When applied to pulse currents of high amplitude, high output diode conductivity results in extreme reverse recovery related losses (14).

3.1.7 Active Network

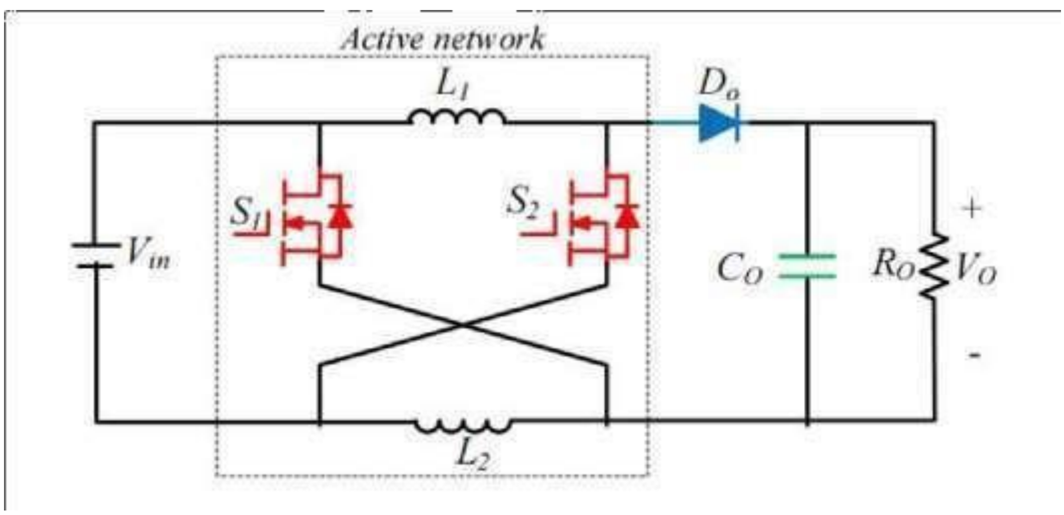


Figure 3.8 Active network converter

The active network converter carries out activities in a manner that is comparable to that of a switch inductor cell [40]. A switched inductor cell, also known as a switched inductor converter, is depicted in Figure 3.8. A switch was installed in place of the two surviving diodes (D1 and D2) after the third diode, denoted by the letter D3, was eliminated during the course of the alteration. The active network converter makes use of two inductors that, in order to generate an architecture that is easier to understand and more compact, can be combined on the same magnetic core. The two inductors that are a part of the active network are charged in parallel and discharged in series when the active switches are turned on. Both of the active switches use the same proportion of PWM duty as the other [42]. The inability of the switched inductor converters to provide a high conversion ratio on their own is the primary drawback of this strategy. This has to do with the fact that the amount of energy held by the two inductors is about equivalent to the voltage that is being fed into the system. As a direct consequence of this, the active network converter has an output voltage that is merely three times higher than the voltage it receives [42]. This voltage gain is a substantially lower value when compared to the gain that is required for a variety of applications. When dealing with high power, it is possible for reverse recovery losses to occur as a consequence of the output diode voltage stress being higher than the output voltage. A further factor that contributes to the complexity of the drive circuitry is the utilisation of active switches that are not coupled to the same reference node. The static gain of the converter can be increased as demonstrated in [41] and [42] by combining an active network converter with a voltage lift cell. Other examples are multi-cell switched inductor/switched capacitor combo active network converters [72] and connected inductors in place of the traditional inductors in an active network converter [71]. Both of these examples may be found in active network converters. Largely in order to achieve higher voltage gain.

3.2 DC-DC Converters with Transformers

Transformers are used commonly in electrical circuits, either with or without galvanic isolation, to step-up or step-down voltage from one level to another and to transfer energy between the source and the load. In addition, transformers are used to step-up or step-down voltage in order to step-up or step-down current. These functions are able to be carried out either with or without the utilization of galvanic isolation. Transformers have a wide variety of applications, the vast majority of which involve matching the impedances of the source and the load. This is the principal role that transformers provide. In order to get the desired results, it is frequently beneficial to integrate a transformer into the switching DC-DC convertera progression of step-ups covering a wide range of voltage conversion ratios. This is due to the fact that the transformer is capable of transforming the voltage at several locations. By making adjustments to the turns ratio of the magnetic element, it is feasible to steer clear of operations with a high duty ratio. One additional benefit of the transformer based converter is that it considerably decreases the strain that the output voltage has on the power switch. This is an advantage that the converter offers. This stress is brought on by the voltage that is being output. Because of this property, it is possible to use power components that have a low onstate resistance and a low voltage; both of these characteristics serve to reduce the amount of conduction loss. It is possible to slow down a diode's current at a controlled rate thanks to the diode's inherent leakage inductance, which in turn helps to reduce the loss caused by reverse recovery. Controlling the intrinsic leakage inductance allows for this to be accomplished. Increasing the number of secondary windings is one way to accomplish providing more than one DC output, which can be done if desired. Some DCDC converters, such as flyback and forward types, use a transformer that serves two purposes: first, it stores energy; second, it enhances voltage by making use of the transformation ratio, which should, in theory, result in a lower total number of magnetic parts. However, a transformer offers a technique to improve the voltage gain in other topologies, such as full and half bridge converters. This can be accomplished by connecting the output of the transformer to the input of the converter. The application of a transformer is required in order to achieve this goal. The study that has been conducted on this subject [10, 43, 44, 48, 50, 73–75] has provided descriptions of a great number of magnetic highstep-up topologies. Depending on the circumstances, the number of turns can be changed in order to accomplish a big static gain (one that is at least ten times greater). On the other hand, a larger turns ratio is a leading indicator of increased winding loss and volume. The size, weight, and volume of the losses that are connected with transformers are further barriers that stand in the way of the development of converters that are both small and efficient. The high turn-off voltage spike of a power device, which is created by the leakage inductance of a transformer, makes EMI problems and switching losses even worse, which both lead to a drop in converter efficiency. The high turn-off voltage spike is caused by a transformer's leakage inductance. When working with a significant amount of power, the primary current that is being transmitted by the transformer is an essential factor. In addition, high-rated power diodes with prolonged switching times are utilized because of the exceptionally high output diode voltage stress [10, 73, 74].

3.2.1 Stacked DC-DC Converters

Locations. This is especially true with regard to converters that are supplied a current supply. Beginning with an isolated converter and working your way backwards, it is possible to design a new non-isolated converter topology by stacking the secondary output side over the primary output side

[44, 76-81]. This can be done by working backwards from the isolated converter. Because of this, the ratio of successful conversions would be higher. The fact that the output is connected in series is the cause of this. Connecting a DC-DC converter's nominal capacitor voltages in series allows for an increase in the output voltage of the converter. This is accomplished by connecting the nominal capacitor voltages in series. The sum of all of the nominal capacitor voltages that are linked in series determines the output voltage of the converter, which is equal to that sum. Numerous isolated converters, particularly current-fed converters, have shown to be excellent options for highstep-up applications in which there is a considerable static gain. This is the case for a number of different high-step-up applications. One of the advantages of utilizing this technology is that it allows for a more even distribution of the voltage stress that is exerted on the semiconductor devices across the body. The efficient recycling of energy is ensured by having a high static gain and having direct inductance to the output side. The voltage stress on the secondary side of the power diodes is significantly reduced as a consequence of this since the vast bulk of the voltage stress on the power diodes is caused by the discrepancy between the voltage at the input and the voltage at the total output. In this design, only a small fraction of the power needs to be altered; the rest of it can be transported from its source all the way to its destination without being affected in any way. The efficiency of the converter improves when it is able to handle the electricity in an effective manner.

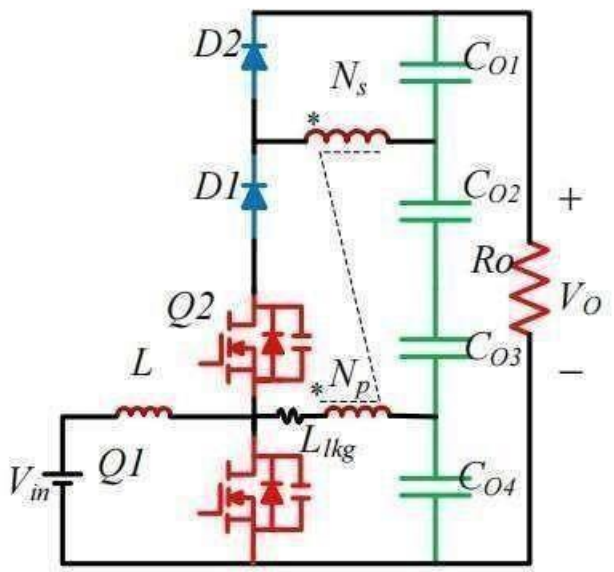


Figure 3.9 Non-isolated stacked converter structure [82]

Figure 3.9 provides a more in-depth illustration of the stacked converter structure than any of the other figures. The boost flyback converter is the most fundamental component of the overall architecture. This converter, which was first introduced in [82] and is produced by combining a normal boost converter with a flyback converter, is the most fundamental construction. It was also the first converter to use a flyback converter. The transformer that was formerly utilized by the flyback converter has been replaced in both converters by a single switch, a boost inductor, and a linked inductor. Additionally, the boost inductor and linked inductor have been connected to each other. The boost converter is able to limit the amount of energy that is wasted due to leaking inductance because it is able to serve as a clamp circuit. This allows the boost converter to save more power. [78] describes a procedure that can be theoretically understood as being comparable to the simultaneous stacking of a boost converter and a sepic converter. Converter. Because the boost and sepic converters use the same filter inductor and power switch, an isolated sepic converter can be used in conjunction with a sepic integrated boost converter to deliver an additional step-up gain. This is made possible by the fact that the boost and sepic converters are both sepic integrated. There are further techniques that can distribute the voltage stress and make up for the insufficient static gain, as shown in [4, 46, and 83]. These methods can be found in [4, 46, and 83]. Increasing the voltage gain typically requires the utilization of a voltage multiplier cell.

The key drawback of this approach is that when a bigger static gain is required, it no longer distributes voltage stress in an equal manner on the secondary side. This is due to the fact that the majority of the voltage stress is impressed on the secondary side. This is because the secondary side is subjected to the bulk of the voltage stress. In addition to this, because there is a direct link between the source of the input and the output, there is a substantial level of audio susceptibility. This is because there is a direct link between the two. In addition, there is a problem with the way the output capacitors are connected in series, which results in an imbalance in the voltage.

3.2.2 The integral Converters

The CCM high step-up boost converter is the architecture that has been shown to be the most effective when it comes to constructing a front-end converter that is capable of producing higher levels of output voltage. This is because it is the topology that utilizes a high step-up converter that is controlled by a CCM. As was covered in the parts that came before it, a high level of efficiency is the most important performance attribute for every application, and it is also one of the most difficult to achieve. This topic was discussed in greater depth in the parts that came before. It is of the utmost importance to keep in mind that neither the magnetic nor the capacitive processes are capable of achieving larger conversion ratios without coming up against some restrictions. This is the case regardless of the method that is being utilized. Simply put, this is something that should not have an excessive amount of emphasis placed upon it. The more traditional method, which is based on the transfer of capacitor charge, is successfully used in voltage multipliers, voltage lifters, switching capacitors, and other electronic components such as these. This is done in order to improve voltage gain. There is only one way to increase the voltage gain in any given circumstance, and that is to significantly increase the amount of components that are considered to be passive. There is no alternative approach that can be taken to achieve this objective. When there are cells that are connected to one another in a series inside the circuit, the circuit takes on a more complicated form, and it is also subjected to a higher degree of current pressure. The capability of the latter to reduce weight (as a result of magnetic technologies) is working against the process of constructing a converter that is very efficient. On the subject of the creation of high-efficiency, high-step-up converters, a significant amount of academic research has been carried out, and as a direct result of this study, a broad variety of methods and topologies have been offered in order to achieve this objective. In order to accomplish high static gain, the bulk of these topologies have focused their attention on integrating or combining magnetic and capacitive techniques in some way.

This has been achieved either by itself or in conjunction with various other approaches. Combining the two strategies is recommended since doing so is useful for three distinct reasons, each of which will be explored in more detail later on in this paragraph. In order to get things rolling, a gain extension cell that has an appropriate duty ratio and makes advantage of a lower turns ratio could be built from scratch. Because of this, the cell could have a reduced turns ratio as a result of the change. This would be conceivable due to the fact that operation with an adequate duty ratio can make it possible to reach the required operating point without causing an excessive strain to be placed on either the current or the voltage. This would allow for the possibility of achieving the desired result. The undertaking may then be carried out successfully as a result of this. It is now possible, as a result of the integration, to make use of devices that have both a low power rating and a low onstate.Resistance, which helps to reduce losses caused by conduction, is an important property of electrical circuits. Thirdly, a smooth switching action may be produced by regulating the current falloff rate of the output diodes by making use of the inherent leakage inductance of the transformer as a guide. This will allow for the generation of a gentle switching action. This can be done to generate a seamless transition from one state to another. In order to have the effect that was envisioned, this is one of the things that can be done. It has been established that decreasing the diode's capacity for reverse recovery has a good impact on electromagnetic interference (EMI) as well as conversion efficiency [13,

14]. This impact has been the topic of a substantial amount of research as well as reportage. As a consequence of this, the integrated converter would result in the production of a converter that is uncomplicated, compact, and made up of a limited number of components. Up to this point, there have been a large number of ideas given for magnetic as well as capacitive high step-up boost converters. Techniques such as coupled inductor and switched capacitor techniques [76, 87–89], coupled inductor and high step-up boost converters [47, 50, 84–86], integrating three-state switching cells and auto transformers [90], and integrating three-state switching cells and voltage multiplier cells [91] are a few examples of the various types of methods that can be used. These are only a few of the many other possible examples that might be found.

The major characteristics of integrated topologies are listed below in the following order:

Correct operation of the duty ratio is made possible by the transformation ratio of the magnetic elements, and increasing the output voltage can be accomplished further by adjusting the turns ratio.

Since they operate at the switching frequency of the converter, the transformer and the other passive components of the converter can be engineered to be lighter and smaller than they would otherwise need to be. This makes it possible for the converter to have a lower overall size.

Low-rated power devices with low on-state resistance can have lower conduction loss because the voltage stress across the devices can be kept much lower than the output voltage by carefully selecting the turns ratio. This allows for the low-rated power devices to have a lower on-state resistance. Because of this, the gadgets may get away with having lower power ratings. In addition, efficiency can be increased by reducing the strain that the current causes on the many components that make up the power supply.

A snubber is often utilized to prevent the turn-off voltage spike that is produced as a result of the energy from the leakage inductance interacting with the parasitic capacitance of the primary switch. This interaction results in the creation of the turn-off voltage spike.

The pace at which the diode's current is falling can be altered by making use of the magnetic element's intrinsic leakage inductance in order to create the effect that is desired.

According to research that has been published, the method that is utilized the majority of the time to recycle the energy that is lost from transformers in DC-DC converters is a clamping solution that can either be active or passive. This technique can be used to recycle the energy. Active clamp circuits offer a number of benefits, the most important of which is the recycling of energy that would otherwise be wasted as a result of leakage inductance. In addition to offering a method for achieving zero voltage switching (ZVS) of both the main and clamp switch [48, 50, 73, 74], active clamp circuits also provide a mechanism for achieving this.

Every active device has the potential to experience a zero voltage transition (ZVT) at some point or another [50]. It is possible for passive clamp circuits to reduce the voltage excursion that is brought on by the leaking of energy that occurs in power devices. Utilizing the circuits will be able to bring about the desired results. Nevertheless, the zero-voltage-switchstate, also known as ZVS, of the primary switch is not provided by the passive circuits [43, 70, 75, and 76]. Despite this, there is no detectable drop in the efficacy of the conversion. Converters that are based on transformers and coupled inductors have the disadvantage of having more input current ripple in high power applications. This is because of the way the connected inductor acts. It is possible to attain a higher power density by utilizing a multiphase current interleaving strategy, which has been detailed [4, 23, 45, 46, 83, 92–103] for the most advanced high step-up boost DC-DC converters. This method may be found in high-step-up boost DC-DC converters are available. Interleaved converters, in addition to having the benefit of being more efficient, also have the benefit of minimizing the amount of current stress that is placed on the device. This benefit is in addition to the benefit that interleaved converters being more efficient. Interleaved architecture is an effective method that may be used to reduce the ripple in the current, minimize the size of the passive components, and improve the converter's sensitivity to transients. Interleaved architecture also minimizes the size of the active components. Utilization of this resource enables one to acquire all of these benefits. It is impossible for the interleaved structure to raise the voltage gain; all it can do is divide the input current of the converter and raise the power density. There is no way for it to result in an increase in the voltage gain. High static gain can be achieved by interleaved DC-DC converters through the utilization of switched capacitor cells, voltage multiplier cells, transformer turns ratios, or any combination of the aforementioned elements [23, 46]. It is possible to achieve this goal by utilizing the aforementioned components in any combination that is most suitable.

Chapter 4 : Experimental Results

4.1 Parameters Estimation

A Proteus 8 platform is used to investigate the performance of the converter and to verify the analytical model.

Table 1: Parameters obtained after compilation with Proteus 8

Table I: Values of Different Parameters of Circuit Fig 2(a,b,c)

Parameters	Values
Input voltage	12V
Switching Frequency (*Fs*)	85kHz
Inductor(*L1*)	50uH
Inductor(*L2*)	50uH
Inductor(*L3*)	50uH
Capacitor(*C1*)	10uF
Capacitor(*C2*)	100uF
Capacitor(*C3*)	330uF
Capacitor(*C4*)	1nF
Load across Capacitor (*C3*) *RL*	100Ω

4.2 Simulation results

The capacitors Cc, C1, and TWCI supply the energy that powers the output capacitor, which is denoted by the letter Co. During this period, the leakage inductance of the TWCI, coupled with the capacitors Cc and C1, will come together to form a resonant tank in the shape of a QR. This will occur because of the resonant tank's ability to produce a resonant frequency. Because of the performance of the QR, the current forms of both the power switch and the output diodes Do have changed into a current that is nearly sinusoidal. This is a direct consequence of the performance of the QR. As we approach the end of this mode, the value of the current that is flowing through the power switch starts to decrease, as can be seen in Figure 1(a), which indicates that we are getting closer to the completion of this mode. As a consequence of this, there is a decrease in the quantity of power that is thrown away when the switch is switched off. Figure 4.2 illustrates the behavior of the ZCS during the turning ON phase of the power switch.

In addition, when the ZCS and LRR requirements are met, the QR operation leads the current of Do to naturally reach zero, which is a desirable result. at t = t2. As a consequence of this, it is fair to predict a significant reduction in the voltage spikes that occur at the switching instants while the DC output voltage is being changed. When Kirchhoff's Voltage Law is applied to the circuit, the resonant frequency (fR) can be found by doing the following:

$$\text{fR} = \frac{1}{T}R = \frac{1}{2\pi\sqrt{Lk[C1][Cc]}} + \cdots \quad (1)$$

The resonant frequency, which is also known as fR, needs to be greater than the switching frequency in order to achieve the most performance out of the suggested architecture. This is because fR stands for "resonant frequency." Under resonance, also known as the 0.5TR DTS zone, is one of the two states that can be formed by the resonant operation. This state is referred to by its abbreviation. However, the critical mode (0.5TR DTS) is the optimal condition for QR operation because it enables the maximum duty cycle (D) to be maintained, it reduces switching and diode reverse recovery losses, and it places the least amount of current strain on the components that are being worked by the circuit. Equations of the following classifications can be presented using this format if they are formatted properly: Vin = vLin (2).

Table II: Values of Different Parameters of Circuit Fig 2(a,b,c)

Parameters	**Values**
Input voltage	12V
Switching Frequency (*Fs*)	85kHz
Inductor(*L1*)	50uH
Inductor(*L2*)	50uH
Inductor(*L3*)	50uH
Capacitor(*C1*)	10uF
Capacitor(*C2*)	100uF
Capacitor(*C3*)	330uF
Capacitor(*C4*)	1nF
Load across Capacitor (*C3*) *RL*	100Ω

According to what is shown in Figure 4(c), the QR operation that takes place during operating mode 2 is finished when the time equals t2. In this mode, the current value on the secondary sides of the TWCI and the current value on the leakage inductance are identical. The capacitor C1 is charged by the current flowing through the coupled inductor's secondary side. Additionally, a linear increase in current is applied to both the magnetizing inductors and the input Lin, quite similarly to how it was done in the mode that came before it. The current flowing through the switch can be represented as the equation isw = Iin + iLm throughout this time period.(8) This mode will be terminated the moment do is turned off when considering the ZCS possibility. in mode 1, from time point t2 to time point t3, given the conditions of a gentle slope and the LRR problem, the current through Do will, on its own accord, reach zero.

At the moment t = t3, the power switch S is turned OFF, which commences mode 4 (the difference in time between t3 and t4 represents the time between these two events). Because of this, the currents that are flowing through the input and leakage inductors cause the clamp diode Dc to become active. These currents are caused by the movement of the inductors themselves. As a direct consequence of this, the clamp circuit, which consists of DC and Cc, is responsible for regulating the maximum voltage stress that is imposed across the power switch. In addition, the leakage inductance of the TWCI is what causes the diode D1 to begin conducting when ZCS conditions are present, as can be seen in Figure 4d. This is the case because the TWCI is a leaking choke. In addition to this, the current that is being supplied by the input inductor starts to charge the clamp capacitor, which is symbolized by the symbol.

$$vLin = Vin - vccA \ ...(9)$$

$$VLM = K \frac{vc1}{n21-1} = \frac{vc2}{n31+n21} \ .....(10)$$

$$Vc2 = (n21 + n31).VLM \ ..... (11)$$

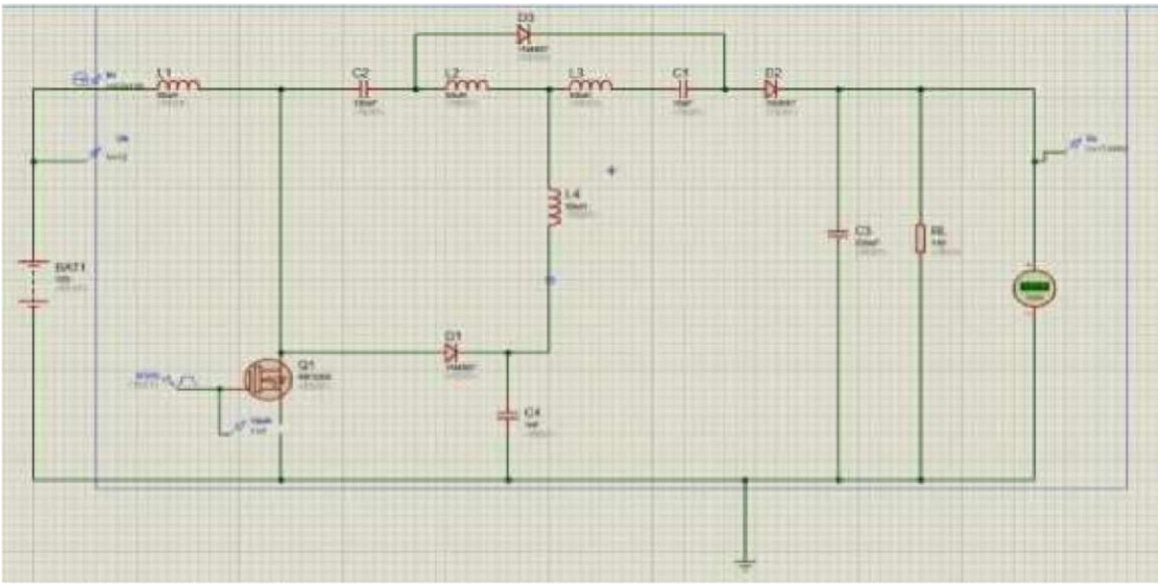


Figure 4.1 : Simulated Circuit SEPIC high-gain dc/dc converter using with Proteus 8

The voltage stress drops to 120 V when the power is switched off, which is a value that is Cc. During this mode, the TWCI acted as the source of power for the capacitor C2. As a direct consequence of this fact, the current that is moving through the input and magnetizing inductors, denoted respectively as iLin and iLM, diminishes in a manner that is linearly progressive. This mode will be exited when the dc current flowing through the diode at the LRR fault reaches zero while the ZCS condition is still active. The following is a list of voltage equations that can be represented using this method: lower than the voltage that is produced by the converter. The findings of the simulation,

which are in agreement with the findings of the study, shed additional insight on the benefits of the proposed topology as well as the passive clamp technique. Investigational Validation

A. Voltage Gain

There is not much time between 1 and 3. As a result, the steady-state analysis can proceed without taking into consideration these intervals. Figure 1 depicts the voltage gain of the recommended converter as a function of the duty cycle for a number of different n21 and n31 values found in the CCM. It is feasible to establish the typical value of the voltage that is placed on the capacitors Cc and

C1 by applying the voltage-second balance law to the input and magnetizing inductors during the switching period. The formula for doing so is as follows.

$$VCc = \frac{Vin}{1-D}$$ …………(13)

$$Vc1 = D.VCc = \frac{D.Vin}{1-D} + \cdots$$ …….(14)

According to the information presented in section 4.1.2, the gating signals are used to derive the converter switches. These signals also act as the PWM duty ratio signal. In addition to this, the gate signals demonstrate that the switches are making appropriate use of the PWM duty ratio. Figure 4.1 depicts the waveform that was measured for the current flowing through the coupled inductor, which is also referred to as the primary current of the leaking inductor. The switching cycle continues without interruption regardless of whether there are any pauses in the current leaking from the inductor. Because of this, it is possible that this mode of operation may be referred to as CCM, which stands for continuous conduction mode. Because of the substantial ripple that was present in the current that was leaking from the inductor in portion

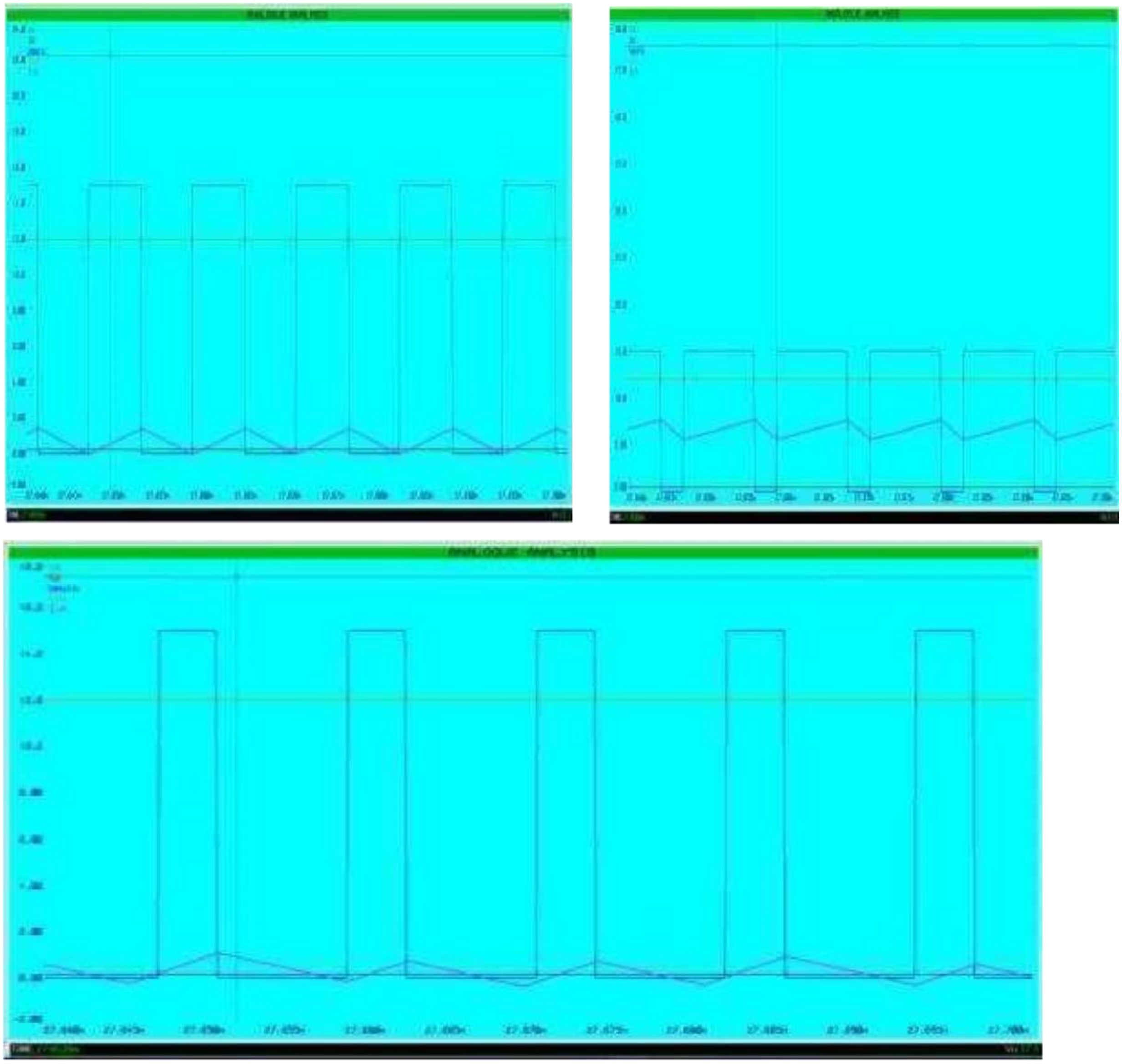


Fig. 4.2 Voltage gain of the proposed converter as a function of duty cycle for different Values **Legends**:

The ability to provide an extremely high voltage gain while simultaneously utilizing a reduced number of turns

A high voltage gain ratio per component

Minimal input ripple;

Tension caused by insufficient voltage; issue with inadequate levels of reverse recovery (LRR);

6) The functionality of all switching components when employing soft switching

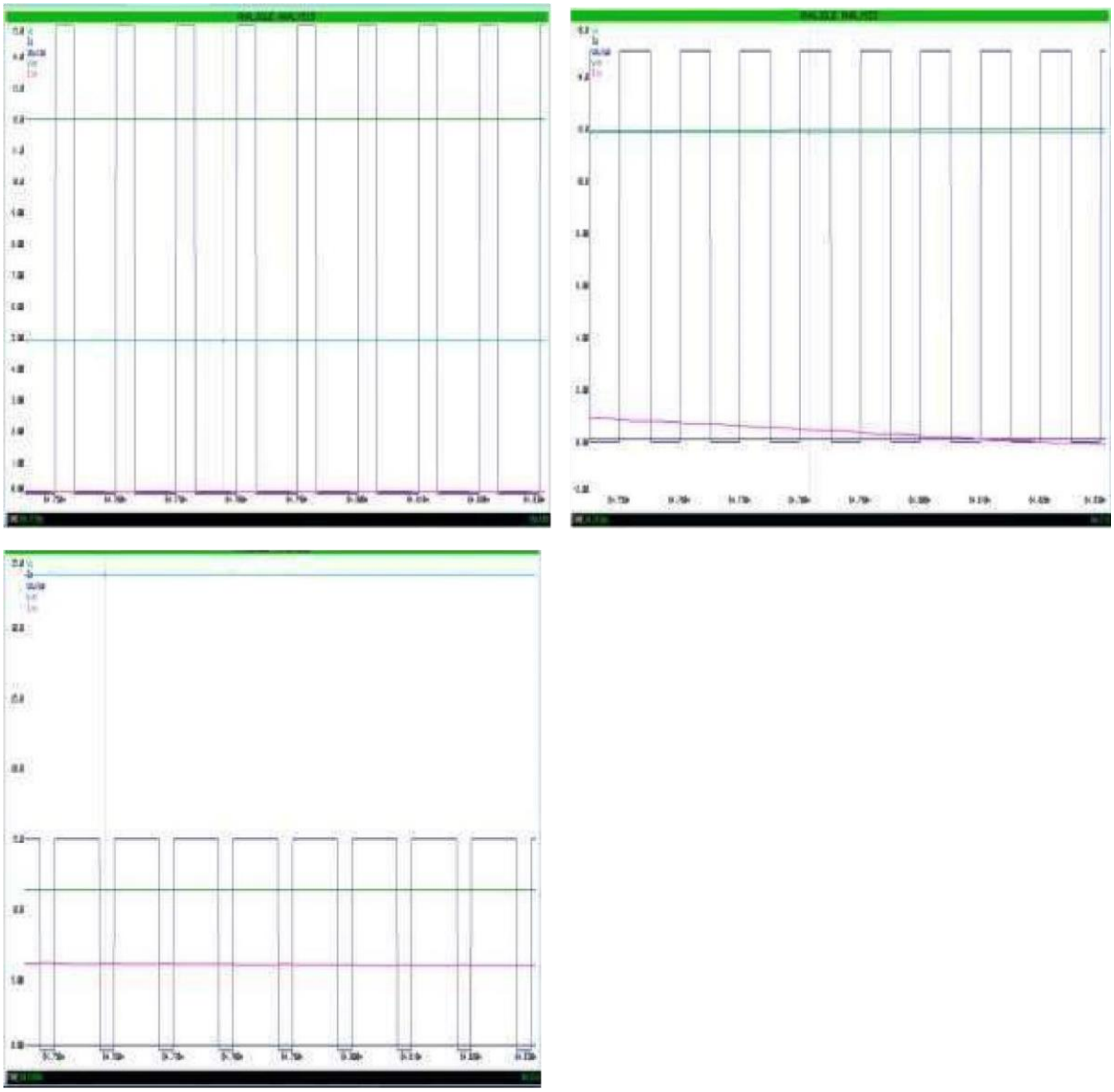
B. Power Device Stress from Voltage and Current

Since the single power switch is clamped by Cc, as was already mentioned, using equation (13), the drain-source voltage stress (VDS) on the single power switch can be calculated as follows.

$$VDS = \frac{Vin}{1-D} = \frac{(n21-1)}{K(n31+n21)+Dn21-D}Vo$$

The net consequence of the reflection current in the secondary windings and the current in the magnetizing inductor while the primary switch on the converter is off. The section of the current ripple that is circled reflects the current that is reflected from the secondary winding. Current measurements taken during peak-to-peak leakage in the inductor show 19 A during the experiment and 20 A during the simulation. The simulation results are shown in Figure

4.3.1 (a), which may be found here.



Simulation Result of Fig 4.3(a),(b),(c)

The subsequent presumptions are formulated during one of the switching phases.

Diodes and switches are considered to be flawless components.

The capacitance of each capacitor is high enough to meet the requirements for being considered steady and free of ripple.

The TWCI is described as an ideal transformer by using a magnetizing inductor, abbreviated as LM, and a leaky inductor, abbreviated as Lk.

4.3 Design Consideration

- Coupled Inductor Turns Ratio Design

The most significant decision to make during the design process is whether to employ a duty cycle that achieves a low turn's ratio and accomplishes the desired voltage gain, or one that selects a linked inductor turns ratio that ensures a modest duty cycle of the power device. Utilising a duty cycle that is capable of realizing a low turns ratio while also accomplishing the necessary voltage gain is the alternative that should be chosen. As was previously said, the turn's ratio is what ultimately determines the voltage and current needs for the switch. Determine the optimal turn's ratio, and make an effort to avoid operating at high duty ratios as the day comes to a close. Both the duty cycle and the turn's ratio of the connected inductors are acquired from (3.15), and they are expressed as

Highstep-up DC-DC Boost Converter. The duty cycle and the turn's ratio of the connected inductors are

Both acquired from (3.15), and they are expressed as such. Examination of the Topology

$$N = \frac{n2}{n1} = [\frac{Vo}{Vin}(1 - D) - 2] \ldots$$

$$D = 1 - \frac{\text{Vin}}{\text{Vo}}(N + 2)$$

A turns ratio of $N = n2/n1 = 1.8$ is chosen which gives a corresponding duty cycle of 0.6

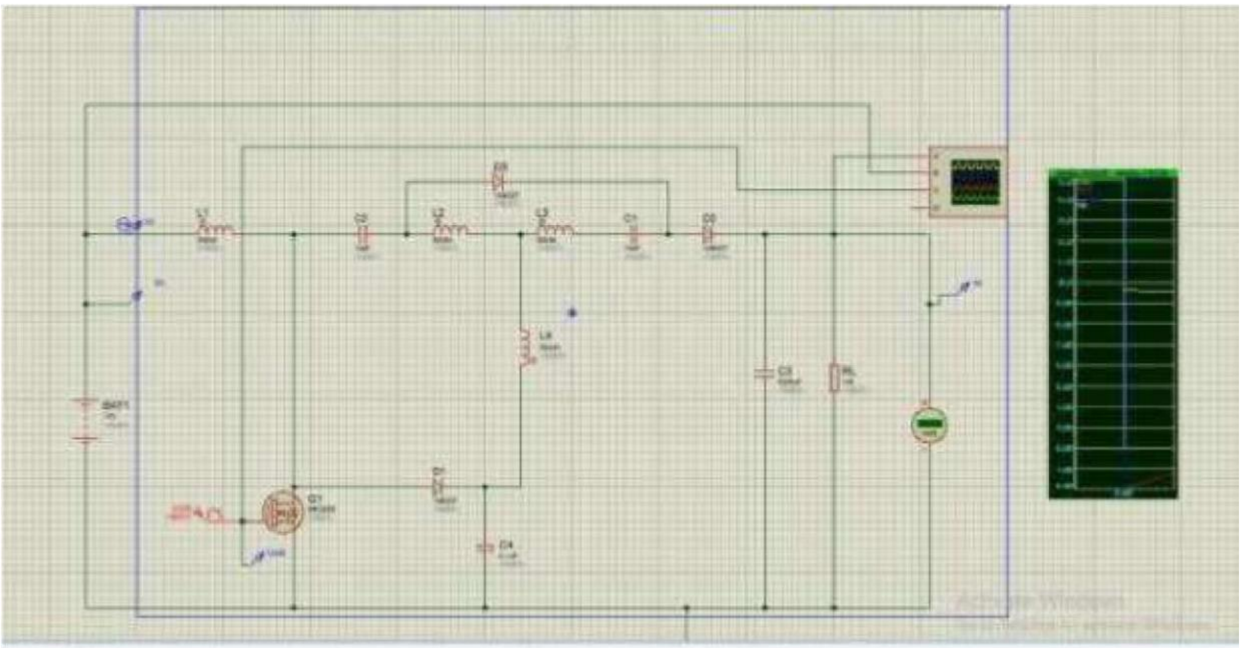
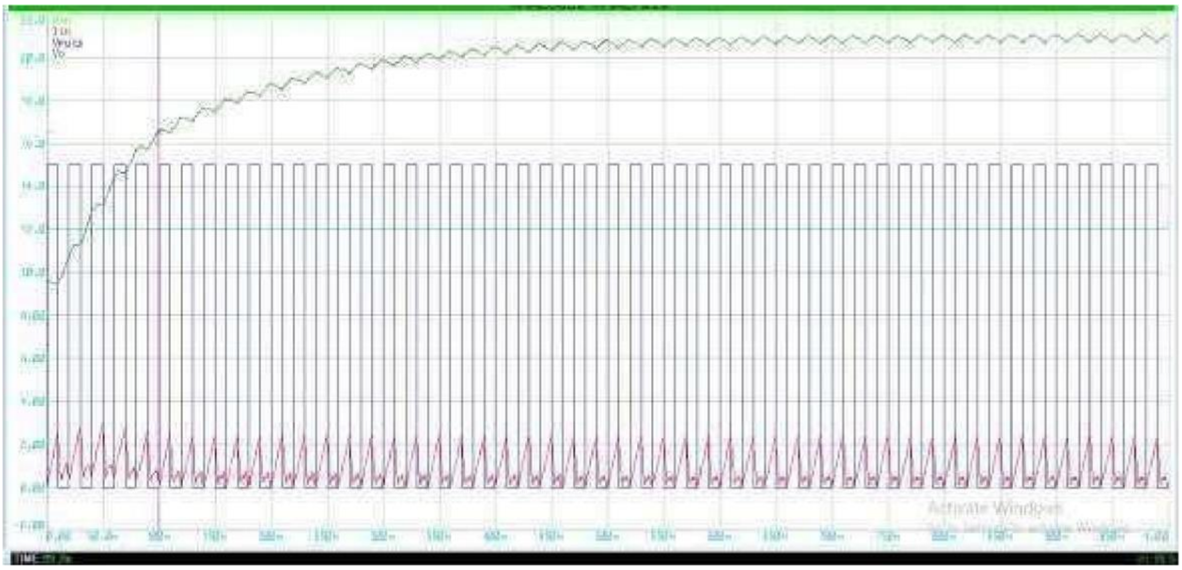


Figure 4.3:non-isolated dc/ dc convertor

The value of D is equal to 0.5 throughout a wide range of n31 values when the duty cycle is held constant. It is self-evident that the voltage gain will experience a significant expansion in proportion to the degree to which n21 is increased in the direction of its value of unity (n211). To put it another way, the performance of this converter cannot be compared to that of the great majority of magnetically coupled converters, in which the voltage gains typically grow in proportion to the turns ratios. This converter does not have this characteristic. It is essential to keep in mind the fact that selecting extremely low values for n21, as demonstrated in Fig. 5, causes the slope of the changes in the voltage gain ratio to become noticeably steeper. This is something that must be taken into consideration. If you choose the required number of turns ratio, it will become increasingly difficult to manage and modify the output voltage gain as the slope gets steeper.

Consequently, picking n21 integers that are extremely near to one should be avoided at all costs. On the other hand, the effects of n21 and n31 on the voltage and current strains imposed on the components of the converter are investigated in the section that comes after this one. Figure 6 also includes a three-dimensional graphic that illustrates the suggested converter voltage gain as a function of n31 and n21 for each of the three different duty cycles, D = 0.3, D = 0.5, and D = 0.75.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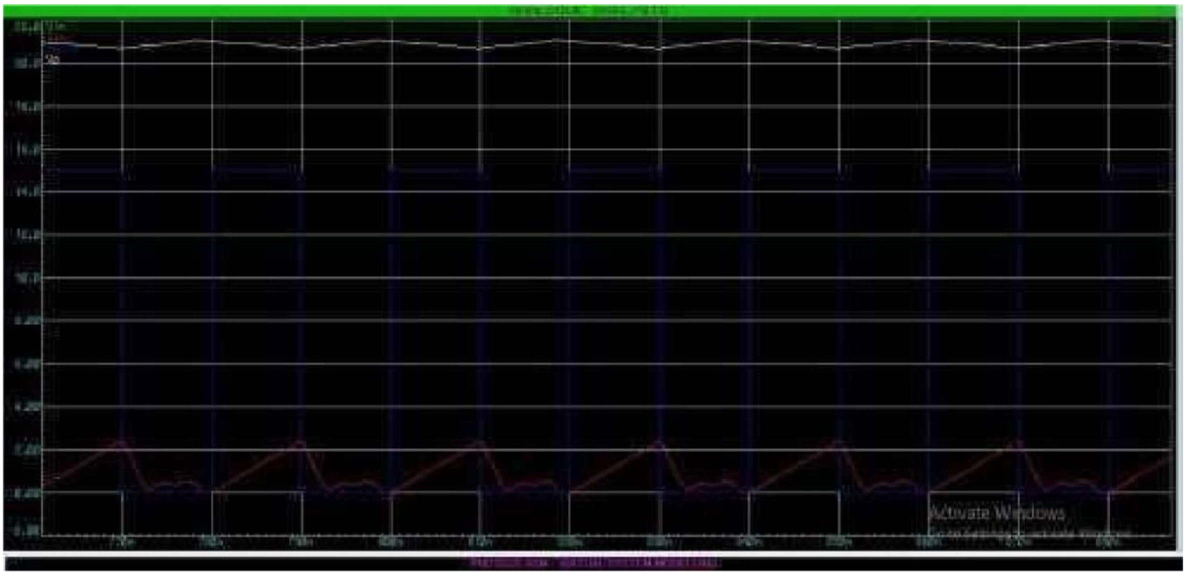
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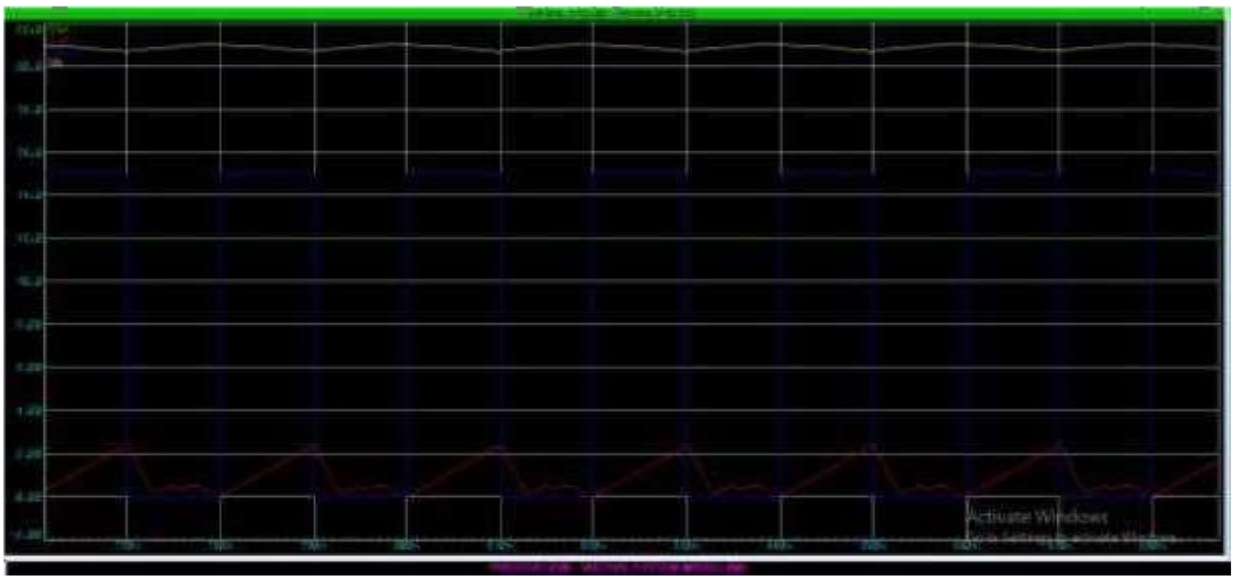
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IDr avg = IDo avg = Io avg is the formula that can be found in section 3.2.2 of the steady state analysis for determining whether or not the average current flowing through the regeneration diode Dr and the output diode Do is equivalent to the output current.(3.25)

The price of regenerative and output diodes is now increasing at a rate that may be described as roughly linear. The peak currents of the diodes are represented by the symbols (3.16 and 3.17), respectively. The input current will flow through the primary switch S whenever it is activated, which will result in the flow of current. When the main switch S is turned off, the currents flowing through the secondary windings and the input winding are combined together.

$$IS\_pk = Iin + \frac{2NiO}{D}$$

If we make the assumption that the power converter has a conversion efficiency of 100 percent (that is, there is no loss), then the relationship between the input and output currents can be represented as

$$IRMS_S = \sqrt{\frac{\int_0^{DTs} is^2(t)dt}{Ts}} = Iin + \sqrt{D + \frac{2N(1-D)}{(N+2)} + \frac{4N^2(1-D)^2}{3D(N+2)^2}} \ldots(3.27)$$

When the main switch S is turned off, the current that is flowing through the clamp switch at the precise moment that it is activated is identical to the current that is flowing through the main switch when it is off. The input current itself is equal to zero, but the clamp switch current at the point of turn-off is equal to the difference between the input current and the current reflected by the regenerative diode. This happens while the clamp switch current itself is equal to the difference between the input current and the current reflected by the regenerative diode. When the clamp switch is in its off position, the following mathematical statement describes the current that travels through the switch:

$$ISC\_OFF = Iin - \frac{2NIO}{(1-D)} \ldots \ldots 3.30)$$

Similarly, the RMS current of the clamped switch is given by.

$$IRMS_{SC} = \sqrt{\frac{\int_{DTs}^{(1-D)Ts} isc2(t)dt}{Ts}}$$

$$= Iin\sqrt{\frac{4N^2(1-D^3)}{3(N+2)^2D^2} - \frac{(2N+D-ND)(N-2)(1-D)}{D(N+2)}} \ldots\ldots\ldots (3.31)$$

$$IRMS\_{SC} = \frac{(N+2)Io}{(1-D)}\sqrt{\frac{4N^2(1-D^3)}{3(N+2)^2D^2} - \frac{(2N+2D-ND)(N-2)(1-D)}{D(N+2)}} \ldots\ldots (3.32)$$

According to equations (3.29 and 3.32), the current stress that is endured by the active devices is a function of both the turn's ratio of the connected inductor as well as its duty cycle. If the turns ratio of the linked inductor is correctly adjusted, it is possible to reduce the current stress that is placed on the primary switch, which will lead to an increase in efficiency.

Chapter 5 : Discussions

The field of energy conversion systems makes considerable use of non-isolated DC-DC converters as a result of their high efficiency as well as their small size. This is due to the fact that non-isolated DC-DC converters are extremely compact. They are utilised in power supplies so that the voltage levels that are generated by the power supplies themselves can be modified. Other than the Boost, BuckBoost, Cuk, Sepic, and Zeta converter topologies, highgain, non-isolated DC-DC converter topologies include a variety of others.

In LED driver circuits, solar power systems, and battery charging circuits, boost converters are a component that can commonly be encountered. Boost converters also play an important role in the production of electrical power. The level of the output voltage will increase to meet the new standard whenever the level of the input voltage is increased. Buck-Boost converters are utilised in all battery-powered equipment, such as electric cars, as well as in renewable energy sources. Some examples of this are solar panels and wind turbines. In addition to that, solar panels and wind turbines may also have these converters. Stepping the level of the input voltage up or down produces either a rise or a decrease in the level of the output voltage, depending on the result that is wanted.

The Cuk converter is a ubiquitous component found in systems that run off of batteries, as well as in portable electronic devices and renewable energy systems. It is also utilized in some systems. It produces voltage amplification, voltage inversion, or voltage decrease. Because of its capability to supply voltage inversion, step-up, step-down, and step-down, and step-down, respectively, LED driver circuits, battery charging circuits, and other circuits present in portable electronic devices frequently make use of the Sepic converter. In varying degrees, the Zeta converter is utilized in LED driver circuits, battery-powered systems, and renewable energy system configurations. It is possible to make either an increase or a decrease in the voltage.

The topology of the appropriate converter is decided on the basis of the needs of the particular application. These needs may include the levels of voltage at both the input and the output, the levels of current, and the power requirements. These high gain non-isolated DC-DC converter topologies are significant components of energy conversion systems because of their exceptional efficiency, compact designs, and great performance. In addition to that, they have outstanding performance.

Amplification of the Converter:

The Boost converter is a voltage step-up converter that creates an output voltage that is greater than the input voltage. This output voltage can be used to power electronic devices. The Boost converter is responsible for generating the output voltage. The converter can be broken down into its component pieces, which are the switch, the inductor, the diode, and the capacitor. When the switch is turned on, the inductor will start charging; when the switch is turned off, the inductor will start discharging, which will result in an increase in the output voltage. When the switch is turned on, the output voltage will be lower. In a wide variety of circuits, such as solar power systems, battery charging circuits, and LED driver circuits, boost converters are a common component that can be found. It operates at high frequencies while preserving an extremely high degree of effectiveness.

Buck-Boost Conversion tool as follows:

The Buck-Boost converter is a type of voltage step-up or step-down converter that has the ability to provide an output voltage that is either higher or lower than the input value. There is a possibility that the output voltage will be lower than the input value, but this is not guaranteed.

This is accomplished by adjusting the voltage during the course of the conversion process so that it is either higher or lower than required. The switch, the inductor, the diode, and the capacitor are the components of the converter that are considered to be of the highest importance. The converter is constructed out of a number of different parts. This behaviour is determined by the duty cycle of the switch, which, when turned on, causes a change in the output voltage. This behaviour is dependent on the duty cycle. This is due to the fact that the inductor charges and discharges itself in alternating cycles, which results in a fluctuating voltage. Buck-Boost converters are used frequently in electric vehicles, renewable energy systems, and other types of equipment that are powered by batteries. Buck-Boost converters can also be used to increase the voltage of a DC current when that function is required. It runs at high frequencies while preserving a high degree of efficiency throughout its operation. A voltage converter that goes by the name of the Cuk converter has the capability to boost the voltage in addition to inverting it or lowering it. It also has the ability to diminish the voltage. A switch, two capacitors, two inductors, and a diode are some of the components that go into the construction of the converter. The Cuk converter is a great option for batterypowered systems, portable electronic devices, and renewable energy systems. This is due to the fact that it has a smaller ripple current and output voltage ripple than other converters.

The Sepic Converter:

The Sepic converter may either step up or step down the voltage, or it can invert the voltage. It also has the ability to invert the voltage. The components that comprise the converter are comprised of a switch, two capacitors, two inductors, and a diode respectively. Because it can keep its output voltage stable over a wide range of input voltages, the Sepic converter is an excellent choice for the circuitry used in portable electronic devices such as LED driver circuits, battery charging circuits, and other circuits associated with these types of devices.

Zeta Converter:

There is more than one form of voltage converter, and one of those types is known as the Zeta Converter. This particular sort of voltage converter has the ability to provide either a step-up or step-down in voltage. The components that go into the construction of the converter are as follows: a switch, two capacitors, two inductors, and a diode. Because of its high efficiency and low output voltage ripple, the Zeta converter is ideally suited for usage in battery powered systems, renewable energy systems, and LED driver circuits. These applications take use of the converter's versatility.

As the topic comes to a close, it is essential to emphasize the necessity of high-gain, nonisolated DC-DC converter topologies in energy conversion systems. This is a crucial issue to bring up. The levels of voltage at the input and output, the amounts of current, and the power requirements for a given application all determine which design is the most effective. Each architecture provides its own one-of-a-kind set of benefits and excels in a particular class of activities more than the others. These converters are used rather frequently in a wide variety of applications, including solar power systems, battery charging circuits, LED driver circuits, electric car charging circuits, and charging circuits for portable electronic devices. Other applications that use these converters include LED driver circuits and electric car charging circuits. They are able to achieve this goal as a result of the outstanding performance that they are able to give in spite of their small size and high level of efficiency.

Chapter 6 : Conclusion

Electrical circuits that are non-isolated DC-DC converters are necessary components in energy conversion systems because they are utilized in applications that demand voltage stepping down or stepping up. This is because these circuits are used to transfer the voltage from one direct current to another direct current. Topologies of high gain converters are preferred because they are able to provide a bigger output voltage for a given input voltage. This makes them more efficient. This contributes to an overall increase in their desirability. Energy conversion systems make extensive use of high-gain non-isolated DC-DC converter topologies such as the Buck-Boost Converter, SEPIC Converter, Cuk Converter, and ukSEPIC Converter, amongst others.

Because the Buck-Boost Converter is capable of producing an output voltage that is either higher or lower than the input voltage, it may be utilized to carry out a high-gain step up or step down operation on the input voltage. This is possible due to the fact that the Buck-Boost Converter can produce an output voltage that is either higher or lower than the input value. This is made possible by the fact that the Buck-Boost Converter is able to output a voltage that is either larger than or lower than the input value. This allows for a wider range of applications. The fact that there are two switches required, on the other hand, makes the scenario significantly more challenging.

In contrast to buck converters, which have input voltages that are always higher than their output voltages, boost converters have input voltages that are always higher than their output voltages. Buck-boost converters have an output voltage that, depending on the duty cycle, can either be lower than or greater than the voltage that is being input into the device. This difference in voltage can be either positive or negative.
The SEPIC Converter is a well-known architecture that can either step up or step down the input voltage depending on which mode it is operating in. It also has a high gain as a result of the numerous inductors and capacitors that it contains, both of which contribute to the overall complexity of the architecture. It is able to perform its functions in either a continuous or discontinuous mode, and it can work with a wide range of voltages that are supplied to it.

In circumstances that call for either a step-up or step-down in the voltage, the Cuk Converter's design, which features two switches, can be put to use thanks to its dual-switch configuration. This is due to the fact that the Cuk Converter consists of two switches. Because the value of the output voltage has the potential to be either higher than or lower than the value of the input voltage, it possesses a considerable gain as a result of this potential difference. The design of the Cuk converter includes the incorporation of a specialised network consisting of inductors and capacitors. This network is what is responsible for the structure of the converter and is also the thing that generates the constant output current.

Depending on the values of the input voltage, the values of the output voltage may depart from the values of the input voltage in either direction. The direction of this deviation is determined by the values of the input voltage. The CUK converter is the component that's to blame for this behaviour. The existence of the inductors will result in a reduction of the harmonics of the currents that are being input as well as those that are being output. This reduction will take place in both directions.

Combining the SEPIC and Cuk converters results in the creation of a new type of converter known as the ukSEPIC Converter. The newly developed form of converter offers a gain that is greater and an efficiency that is greater than any of the individual converters. It is able to function in either a continuous or discontinuous mode and can manage a diverse assortment of voltages that are fed into it. Additionally, it may act in either way. In addition, it is possible for it to operate in either mode simultaneously.

The process of choosing the topology for a non-isolated DC-DC converter can be influenced by a large number of different variables in different ways. These considerations include the voltage range on both the input and the output, the efficiency of the device, its size, and its price. Prior to choosing on a course of action, it is vital to give the question of which converter topology will serve a particular application in the most effective manner a lot of thought before making a decision on what to do next. High gain converter topologies, such as the ones that were reviewed above, have the potential to deliver significant benefits in a wide variety of settings and situations.

It is vital that when selecting the appropriate converter topology, the relevance of high gain nonisolated DC-DC converter topologies in energy conversion systems be taken into consideration in order to guarantee that the performance of the system is maximised to the greatest extent that is practically possible. This is because it is the only way to ensure that the performance of the system is maximised to the greatest degree that is practically possible. Because of this, the performance of the system will be able to be maximised to the utmost extent that is practically achievable.

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