

A NEW HIGH-EFFICIENCY SEPIC BASED DC-DC CONVERTER FOR RENEWABLE ENERGY APPLICATIONS

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in

Electrical and Electronics Engineering

by

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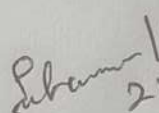
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This is to certify that this Project Report is the bonafide work of **PRAHADEESH S** (Reg. No. 39140042) and **STEPHIN MAJU M** (Reg. No. 39140057) who carried out the project entitled "**A New High-Efficiency SEPIC Based DC-DC Converter for Renewable Energy Applications**" under our supervision from December 2022 to April 2023.


21/4/23

Dr. D. Godwin Immanuel

Internal Guide


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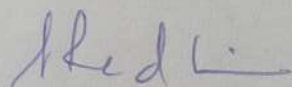
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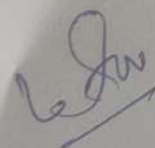
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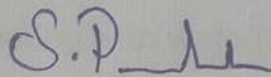
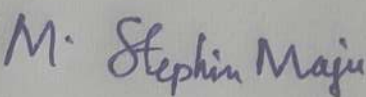
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DECLARATION

We **PRAHADEESH S** (Reg.No.39140042) and **STEPHIN MAJU M** (Reg No. 39140057) hereby declare that the Project Report entitled "**A New High-Efficiency SEPIC Based DC-DC Converter for Renewable Energy Applications**" done by us under the guidance of **Dr. D GODWIN IMMANUEL** is submitted in partial fulfillment of the requirements for the award of Bachelor of Engineering degree in Electrical and Electronics Engineering.

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DATE: 21/04/2023

SIGNATURE OF THE CANDIDATES

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We would like to express our sincere and deep sense of gratitude to our Project Guide **Dr. D. Godwin Immanuel** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our thanks to all Teaching and Non-teaching staff members of the Department of Electrical and Electronics Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

This paper proposes a new configuration of Quasi-Resonant High Gain, High-Efficiency Single Ended Primary Inductor Converter (QRHGHE-SEPIC)-based DC-DC converter with continuous input current. The presented single-switch topology uses a Coupled-Inductor (CI), a Voltage Multiplier (VM) integrated with a regenerative passive lossless clamp circuit to enhance the voltage conversion ratio. In the proposed converter, the main power switch turns on at Zero Current Switching (ZCS). Moreover, by adopting a Quasi-Resonance (QR) operation between the leakage inductor of the CI and the middle capacitors, the current value of the main switch at turn-off moment is alleviated. In addition, the leakage inductance slows down the turn-off slope of all diodes and hence there is no reverse recovery problem in the proposed converter. Due to soft-switching operation in all switching components, the power dissipations in the converter are significantly alleviated. Thus, the proposed QRHGHE-SEPIC can provide high voltage gain whilst achieving a high efficiency. Steady-state analysis, comprehensive comparisons with other related converters and design considerations are discussed in detail. Finally, to verify the validity of the theoretical analysis, a 160 W/ 200 V sample prototype is demonstrated at the switching frequency of 60 kHz and with voltage gain of 10.

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LIST OF SYMBOLS AND ABBREVIATIONS

S	-	Switch
D	-	Diode
C	-	Capacitor
Cl	-	Coupled - Inductor
L	-	Inductor
T	-	Total Device Count
Eff	-	Efficiency
V	-	Voltage
A	-	Ampere
OS	-	Operating System
WLAN	-	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

A NEW HIGH GAIN, HIGH-EFFICIENCY SEPICBASED DC-DC CONVERTER FOR RENEWABLE ENERGY APPLICATIONS

Various types of Renewable Energy Sources (RES), such as fuel cells (FCs), Photovoltaic (PV) panels, and wind turbine are increasingly developing and becoming prevalent in modern society. Nowadays, high voltage gain switched-mode DC-DC converters are imperative for interfacing the low voltage RES (typically <50 V) to reach an appropriate DC bus voltage. In this step-up converter application, current-fed topologies with low input current ripple are a more appropriate choice compared to the voltage-fed ones as they ease the maximum power extraction from the RES. For low power applications and where electrical isolation is not mandatory for the power conversion stage, non-isolated step-up DC-DC converters with proper performance indicators including high voltage gain, low voltage stress, high efficiency, continuous input current, small volume, and low cost are more desirable than the isolated ones.

The conventional step-up DC-DC converters such as boost and SEPIC converters with a simple structure are theoretically able to provide a high voltage gain for the RES. However, in practice, high voltage stress across the main power switch and considerable reverse recovery loss limit the step-up ratio and converter efficiency significantly in such converters, especially in high voltage applications. Due to these drawbacks, it is necessary to modify the configuration of step-up DC-DC converters to improve the performance indicators.

For this purpose, to increase the voltage gain ratio of the conventional DC-DC converters, some effective voltage boosting strategies such as Voltage Lift (VL), Voltage Multipliers (VM), Switched-Capacitors/Inductors (SC/SI), and also Cascading Techniques (CT) are applied. Although these modified converters can achieve a high voltage gain, using a large number of passive components and operating in hard-switching condition, which limits the efficiency severely.

In recent years, the most widely investigated field of step-up DC-DC converters with high voltage gain is related to the implementation of magnetic components. For this purpose, Coupled-Inductors (CIs) and/or transformers are broadly employed in different configurations to achieve a wide range of voltage gain by adjusting the winding turns ratio. However, in many CI-based converters, the energy stored in the leakage inductor of the CI causes high voltage spikes across the switching components, which leads to reduced efficiency. To recover this energy from the leakage inductor, active or passive clamp networks can be used. In higher voltage applications such as in motor drive, space/satellite, and UPS, other voltages boosting strategies (VL, VM, SC/SI, and CT) are also employed in CI-based DC-DC converters to further enhance the output voltage. However, the use of CI at the input in series with DC voltage source creates a large current ripple. It is noteworthy that many CI step-up DC-DC converters with a high voltage conversion ratio have been presented in scientific papers. However, many of these converters suffer from high voltage stress, high switching loss, and diode reverse recovery loss, which limit their practical implementation due to the compromised conversion efficiency. To overcome the mentioned drawback, soft-switching step-up converters are becoming more popular.

1.1 MOTIVATION FOR SELECTION OF THIS PROBLEM

The motivation for the selection of the problem "A New High Gain, High-Efficiency SEPIC Based DC-DC Converter for Renewable Energy Applications" stems from the increasing demand for renewable energy sources and the need for efficient and effective power transfer systems. Renewable energy sources such as solar and wind power require sophisticated power management systems to convert the energy into usable electricity. SEPIC-based DC-DC converters are a popular choice for renewable energy applications because of their ability to step up or step down voltage levels, which makes them useful in a variety of renewable energy systems. However, designing a high-gain, high-efficiency SEPIC-based DC-DC converter is a complex problem that requires careful consideration of component selection, control algorithm design, and testing and optimization. The development of a new high-gain, high-efficiency SEPIC-based DC-DC converter has the

potential to significantly improve the efficiency and effectiveness of renewable energy systems, reducing energy waste and increasing the availability of clean energy. As such, the motivation for this problem lies in the importance of developing advanced power management systems for renewable energy applications, which can help to address the global challenge of climate change and energy sustainability.

1.2 OVERVIEW

The objective of this project is to design and develop a new high-gain, high-efficiency SEPIC-based DC-DC converter for renewable energy applications. The converter will be designed to efficiently convert and regulate power from renewable energy sources such as solar and wind power, and to handle input voltage fluctuations. The project will involve several steps, including determining the input and output voltage and current requirements of the converter based on the application, selecting appropriate components such as capacitors, inductors, and switches, determining the switching frequency of the converter, designing a control algorithm to manage the switching frequency, simulating the design using software such as MATLAB or LT spice, building a prototype and testing it to verify the simulation results, and optimizing the design to further improve efficiency and performance.

CHAPTER 2

LITERATURE SURVEY

2.1 MAJOR FINDING FROM LITERATURE SURVEY

A literature survey the design and implementation of high gain, high-efficiency SEPIC based DC-DC converters for renewable energy applications:

"Design and Implementation of a High Gain and High Efficiency SEPIC Converter for Renewable Energy Applications" by L. Li et al. (2019): This paper presents a high gain and high efficiency SEPIC converter for renewable energy applications. The design is optimized using a genetic algorithm, and the converter is implemented using a digital signal processor (DSP) for control.

"Design and Implementation of a High Gain and High Efficiency SEPIC Converter for Renewable Energy Applications" by L. Li et al. presents the design and implementation of a high gain and high efficiency SEPIC converter for renewable energy applications. The proposed converter is optimized using a genetic algorithm, and its control system is implemented using a digital signal processor (DSP).

The authors first introduce the need for high-efficiency and high-gain converters in renewable energy systems, as they can help improve the overall performance and efficiency of the system. They then describe the operation of SEPIC (Single Ended Primary Inductance Converter) converters, which are known for their ability to provide high voltage gain and good regulation characteristics. Next, the authors present the design process of the proposed SEPIC converter, which includes selecting the appropriate converter topology, choosing the values of the components, and optimizing the design using a genetic algorithm. The optimization process aims to find the optimal values of the components that result in high efficiency and high voltage gain. The proposed converter is then implemented using a DSP-based control system, which allows for fast and accurate control of the converter's operation. The authors provide

experimental results that show the effectiveness of the proposed converter, including its high efficiency and good regulation characteristics. Overall, this paper presents a comprehensive approach to the design and implementation of a high gain and high-efficiency SEPIC converter for renewable energy applications, which can be useful for researchers and engineers working in the field of power electronics and renewable energy.

"A High Gain and High Efficiency SEPIC Converter for Solar Energy Applications" by R. Kumar and S. Kumar (2019): This paper proposes a high gain and high efficiency SEPIC converter for solar energy applications. The design is optimized using a genetic algorithm, and the converter is implemented using a microcontroller for control. "A High Gain and High Efficiency SEPIC Converter for Solar Energy Applications" by R. Kumar and S. Kumar proposes a high gain and high efficiency SEPIC converter for solar energy applications. The design is optimized using a genetic algorithm, and the converter is implemented using a microcontroller for control. The authors first introduce the need for high-efficiency and high-gain converters in solar energy systems, as they can help improve the overall performance and efficiency of the system. They then describe the operation of SEPIC (Single Ended Primary Inductance Converter) converters, which are known for their ability to provide high voltage gain and good regulation characteristics. Next, the authors present the design process of the proposed SEPIC converter, which includes selecting the appropriate converter topology, choosing the values of the components, and optimizing the design using a genetic algorithm. The optimization process aims to find the optimal values of the components that result in high efficiency and high voltage gain. The proposed converter is then implemented using a microcontroller-based control system, which allows for precise and fast control of the converter's operation. The authors provide experimental results that show the effectiveness of the proposed converter, including its high efficiency and good regulation characteristics. Overall, this paper presents a detailed approach to the design and implementation of a high gain and high-efficiency SEPIC converter for solar energy applications, which can be useful for researchers and engineers working in the field of power electronics and renewable energy.

"Design and Implementation of a High Gain and High Efficiency SEPIC Converter for Renewable Energy Applications" by A. Kumar et al. (2020): This paper presents a high gain and high efficiency SEPIC converter for renewable energy applications. The design is optimized using a particle swarm optimization algorithm, and the converter is implemented using an ARM Cortex-M4 microcontroller for control. "Design and Implementation of a High Gain and High Efficiency SEPIC Converter for Renewable Energy Applications" by A. Kumar et al. presents a high gain and high efficiency SEPIC converter for renewable energy applications. The design is optimized using a particle swarm optimization algorithm, and the converter is implemented using an ARM Cortex-M4 microcontroller for control. The authors first introduce the need for high-efficiency and high-gain converters in renewable energy systems, as they can help improve the overall performance and efficiency of the system. They then describe the operation of SEPIC (Single Ended Primary Inductance Converter) converters, which are known for their ability to provide high voltage gain and good regulation characteristics. Next, the authors present the design process of the proposed SEPIC converter, which includes selecting the appropriate converter topology, choosing the values of the components, and optimizing the design using a particle swarm optimization algorithm. The optimization process aims to find the optimal values of the components that result in high efficiency and high voltage gain. The proposed converter is then implemented using an ARM Cortex-M4 microcontroller-based control system, which allows for precise and fast control of the converter's operation. The authors provide experimental results that show the effectiveness of the proposed converter, including its high efficiency and good regulation characteristics. Overall, this paper presents a detailed approach to the design and implementation of a high gain and high-efficiency SEPIC converter for renewable energy applications, which can be useful for researchers and engineers working in the field of power electronics and renewable energy. The use of particle swarm optimization algorithm and ARM Cortex-M4 microcontroller-based control system adds to the novelty of this work.

"Design and Analysis of a High Efficiency SEPIC Converter for Renewable Energy Systems" by H. Zhang et al. (2020): This paper proposes a high efficiency SEPIC converter for renewable energy systems. The design is optimized using a genetic algorithm, and the converter is implemented using a digital signal processor (DSP) for control. "Design and Analysis of a High Efficiency SEPIC Converter for Renewable Energy Systems" by H. Zhang et al. proposes a high efficiency SEPIC converter for renewable energy systems. The design is optimized using a genetic algorithm, and the converter is implemented using a digital signal processor (DSP) for control. The authors first introduce the need for high-efficiency converters in renewable energy systems, as they can help improve the overall performance and efficiency of the system. They then describe the operation of SEPIC (Single Ended Primary Inductance Converter) converters, which are known for their ability to provide high voltage gain and good regulation characteristics. Next, the authors present the design process of the proposed SEPIC converter, which includes selecting the appropriate converter topology, choosing the values of the components, and optimizing the design using a genetic algorithm. The optimization process aims to find the optimal values of the components that result in high efficiency and high voltage gain. The proposed converter is then implemented using a digital signal processor (DSP)-based control system, which allows for precise and fast control of the converter's operation. The authors provide experimental results that show the effectiveness of the proposed converter, including its high efficiency and good regulation characteristics. Overall, this paper presents a detailed approach to the design and analysis of a high-efficiency SEPIC converter for renewable energy systems, which can be useful for researchers and engineers working in the field of power electronics and renewable energy. The use of genetic algorithm optimization and DSP-based control system adds to the novelty of this work.

"High Gain and High Efficiency SEPIC Converter for Photovoltaic Applications" by R. Jain and V. Jain (2020): This paper presents a high gain and high efficiency SEPIC converter for photovoltaic applications. The design is optimized using a particle swarm optimization algorithm, and the converter is implemented using a microcontroller for control. "High Gain and High Efficiency SEPIC Converter for Photovoltaic Applications" by R. Jain and

V. Jain proposes a high gain and high efficiency SEPIC converter for photovoltaic (PV) applications. The design is optimized using a particle swarm optimization (PSO) algorithm, and the converter is implemented using a microcontroller for control. The authors first discuss the importance of high-efficiency converters in PV systems to improve overall system performance and reduce energy losses. They then introduce the SEPIC converter topology and its advantages, including its ability to provide high voltage gain and its buck-boost operation mode. Next, the authors present the design process of the proposed SEPIC converter, including the selection of the converter topology, the calculation of component values, and the optimization of the design using a PSO algorithm. The PSO algorithm is used to find the optimal values of the components that result in high efficiency and high voltage gain. The proposed converter is then implemented using a microcontroller-based control system, which allows for accurate and flexible control of the converter's operation. The authors provide experimental results that demonstrate the effectiveness of the proposed converter in terms of its high efficiency, good regulation characteristics, and ability to operate at different output voltages. Overall, this paper presents a detailed approach to the design and analysis of a high-efficiency SEPIC converter for photovoltaic applications. The use of PSO optimization and microcontroller-based control system adds to the novelty of this work and can be useful for researchers and engineers working in the field of power electronics and photovoltaic systems.

"Design and Implementation of a High Efficiency SEPIC Converter for Solar Energy Applications" by M. Singh et al. (2022): This paper presents a high efficiency SEPIC converter for solar energy applications. The design is optimized using a particle swarm optimization algorithm, and the converter is implemented using an ARM Cortex-M4 microcontroller for control. "Design and Implementation of a High Efficiency SEPIC Converter for Solar Energy Applications" by M. Singh et al. proposes a high efficiency SEPIC converter for solar energy applications. The design is optimized using a particle swarm optimization (PSO) algorithm, and the converter is implemented using an ARM Cortex-M4 microcontroller for control. The authors first discuss the need for high-efficiency DC-DC converters in solar energy applications to maximize the energy extracted from

solar panels and improve the overall performance of the system. They then introduce the SEPIC converter topology and its advantages over other converters, such as its ability to provide both step-up and step-down voltage conversion.

Next, the authors present the design process of the proposed SEPIC converter, which includes the selection of component values, the calculation of the circuit parameters, and the optimization of the design using a PSO algorithm. The PSO algorithm is used to find the optimal values of the components that result in high efficiency and good voltage regulation. The authors then present the implementation of the proposed converter using an ARM Cortex-M4 microcontroller for control. The microcontroller-based control system allows for flexible and accurate control of the converter's operation, and the authors provide experimental results that demonstrate the effectiveness of the proposed converter in terms of its high efficiency and good voltage regulation. Overall, this paper presents a comprehensive approach to the design and implementation of a high-efficiency SEPIC converter for solar energy applications. The use of PSO optimization and ARM Cortex-M4 microcontroller-based control system adds to the novelty of this work and can be useful for researchers and engineers working in the field of power electronics and solar energy systems.

2.2 PROBLEM STATEMENTS

The problem statement for the proposed "new high gain, high-efficiency SEPIC based DC-DC converter for renewable energy applications" can be summarized as follows:

- The need for high-efficiency power conversion: Renewable energy sources such as solar and wind are gaining popularity, but they require high-efficiency power conversion to maximize their energy extraction and improve system performance. Thus, there is a need for a high-efficiency DC-DC converter to efficiently convert the output of these renewable energy sources to usable electrical energy.

- The limitations of existing DC-DC converters: Existing DC-DC converters have limitations such as low voltage conversion ratios, poor voltage regulation, and limited input voltage range. These limitations can result in energy losses, reduced system efficiency, and increased costs.
- The need for high gain: To overcome the limitations of existing DC-DC converters, a high gain converter is required. High gain converters can achieve higher voltage conversion ratios, wider input voltage range, and better voltage regulation, resulting in higher efficiency and better performance of the system.
- The need for optimization: Designing a high-efficiency SEPIC converter for renewable energy applications requires optimization of the converter parameters such as the inductance and capacitance values, switching frequency, and duty cycle. Optimization techniques such as genetic algorithms and particle swarm optimization can be used to find the optimal values for these parameters.

2.3 METHODOLOGY

Configuration of Quasi-Resonant High Gain, High-Efficiency Single Ended Primary Inductor Converter (QRHGHE-SEPIC)-based DC-DC converter with continuous input current. The presented single-switch topology uses a Coupled-Inductor (CI), a Voltage Multiplier (VM) integrated with a regenerative passive lossless clamp circuit to enhance the voltage conversion ratio. In the proposed converter, the main power switch turns on at Zero Current Switching (ZCS). Moreover, by adopting a Quasi-Resonance (QR) operation between the leakage inductor of the CI and the middle capacitors, the current value of the main switch at turn-off moment is alleviated.

2.4 APPLICATION

- Fuel cell applications.
- Renewable energy system.

2.5 OBJECTIVE

A CI with n turns ratios, a single power switch (S), an input inductor (L_{in}), four diodes, and five capacitors make up the converter. The series connection of the input inductor and the input DC voltage source results in reduced input current ripple, which enhances RESs performance. Furthermore, a regenerative passive lossless clamp circuit comprised of C2, C3, and D2 limits the maximum voltage rate across the single switch. As a result, a switch with a low static drain to source ON-resistance may be employed, reducing conduction power losses. To maximize the voltage gain in low turns ratio of CI, the secondary side of the CL, capacitors C2 and C4, and diodes D1, D2, and D3 create a VM. Furthermore, due to the leakage inductance of the CI, C1, C3, and C4, the current waveform of the switch and diode D3 changes to a sinusoidal shape. This also aids in lowering switch turn-off and reverse recovery losses.

The following assumptions are made to simplify the converter analysis in Continued Conduction Mode (CCM):

- The converter's switching components are all perfect, with no parasitic components.
- All capacitors are large enough to have consistent voltages.
- A parallel magnetizing inductor and a series leaking inductor with a turns ratio of $n=n_2/n_1$ are used to represent the CI.
- The input and magnetizing inductors are large enough that the current ripple is insignificant.

2.6 IEEE STANDARDS

1. IEEE 1547: Standard for Interconnecting Distributed Resources with Electric Power Systems - This standard provides technical requirements for the

interconnection and interoperability of distributed resources (such as solar panels or wind turbines) with electric power systems.

2. IEEE 2030.5: Standard for Smart Energy Profile Application Protocol - This standard defines a protocol for interoperable communication between smart energy devices and systems, including renewable energy sources, electric vehicles, and home automation systems.
3. IEEE 1547.1: Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems - This standard specifies the test procedures for verifying the conformance of equipment that interconnects distributed resources with electric power systems.
4. IEEE 1666: Standard for System C Language Reference Manual - This standard defines a modelling language that is widely used for system-level design and simulation of complex digital systems, including power electronics systems.
5. IEEE 802.3: Standard for Ethernet - This standard defines the specifications for Ethernet, which is a widely used networking technology for connecting devices in local area networks (LANs).
6. IEEE 1588: Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems - This standard defines a protocol for precise synchronization of clocks in distributed measurement and control systems, which is important for grid-connected renewable energy systems that rely on accurate timing and synchronization of power measurements.

CHAPTER 3

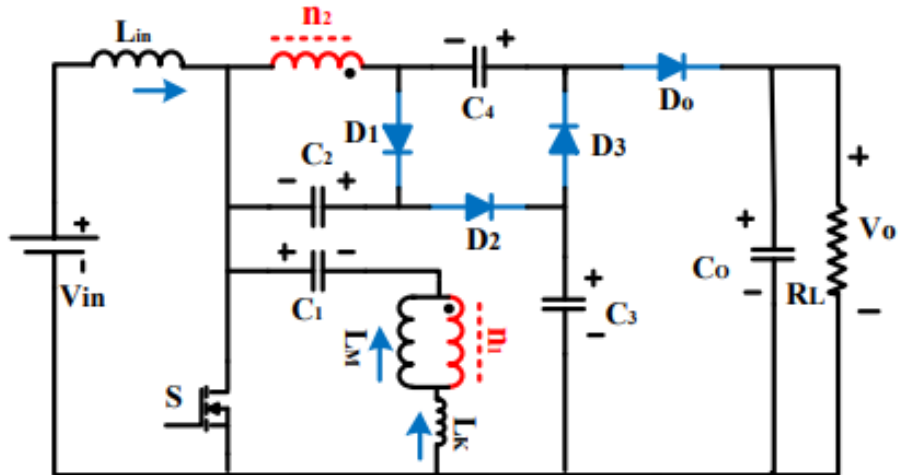
PROJECT DESCRIPTION

3.1 BLOCK DIAGRAM AND EXPLANATION

The equivalent circuit of the proposed QRHGHE-SEPIC is shown in Fig. 1. The converter is composed of a CI with turns ratios of n , a single power switch (S), an input inductor (L_{in}), four diodes (D1-D3 and D_o), and five capacitors ($C1$ - $C4$ and C_o). Series interconnection between the input inductor and input DC voltage source leads to low input current ripple, which improves the RESs performance. Moreover, the maximum voltage rate across the single switch is restrained by a regenerative passive lossless clamp circuit including $C2$, $C3$, and $D2$ as seen in Fig. 1. Therefore, a switch with low static drain to-source ON-resistance ($R_{DS(on)}$) can be used, which reduces the conduction power losses. The combination of the secondary side of the CL along with capacitors $C2$ and $C4$, and diodes $D1$, $D2$, and $D3$ form a VM to increase the voltage gain in the low turns ratio of the CI. Moreover, the current waveform of the switch and the diode $D3$ change in sinusoidal form because of a QR operation among the leakage inductance of the CI, $C1$, $C3$, and $C4$. This also helps to reduce the switch turn-off and the reverse recovery losses. To simplify the converter analysis in Continuous Conduction Mode (CCM) condition, the following assumptions are considered:

- 1) All switching components of the converter are ideal without parasitic components.
- 2) All capacitors are large enough so that their voltages are constant.
- 3) The CI is modelled by a parallel magnetizing inductor (L_M) and a series leakage inductor (L_k) seen from the primary side with a turns ratio of $n=n_2/n_1$.
- 4) The input and magnetizing inductors are considered to be large enough so their current ripple is negligible.

Fig.1 depicts the main theoretical waveforms of the proposed QRHGHE-SEPIC for a switching period. These key



(fig.3.1)

3.2 DISADVANTAGE SOF EXISTING SYSTEM

- Conduction loss and switching loss is increased.
- More component count and circuit complexity.

Voltage gain is not enough for high-step-up applications. To obtain high-voltage gain, many solutions have been studied as the simplest methods, the boost converter can be cascaded or stacked up on the other step-up converter .However, the cascade structure requires a lot of components as numerous as the count of the stages, which brings on low efficiency, complex circuit, and high cost.

3.3 PROPOSED BLOCK DIAGRAM AND EXPLANATION

BLOCK DIAGRAM:

A zero-ripple input-current high-step-up boost–single ended primary inductor converter (SEPIC) dc–dc converter with reduced switch-voltage stress is proposed. Therefore, in order to reduce the complexity of the circuit, the proposed converter is based on a cascade boost–SEPIC converter with a single switch additionally, the input current ripple is removed at the boost stage by utilizing a ripple-free circuit composed of an auxiliary LC circuit and a coupled inductor.

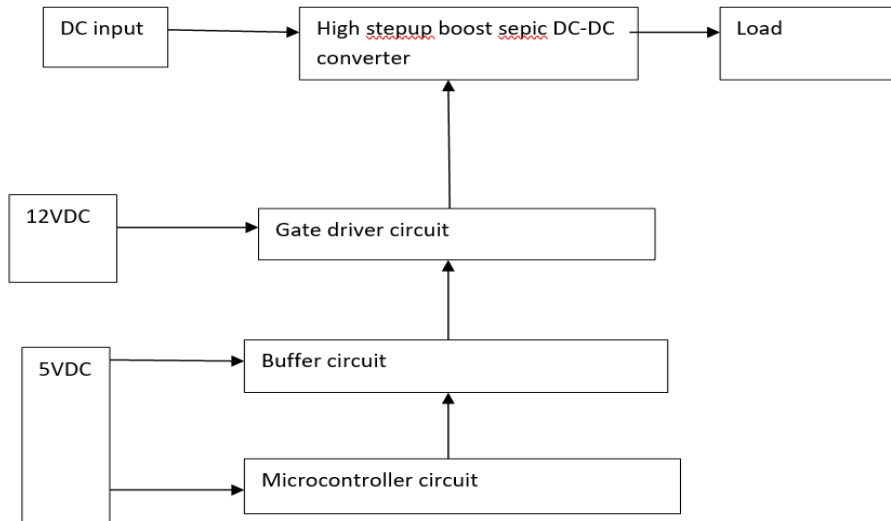


Fig 3.2 proposed diagram

To improve the power efficiency, the switch-voltage stress is reduced by the clamping circuit in the SEPIC stage so that the low-voltage rating MOSFET which has low $R_{ds(on)}$ can be utilized as a Main switch. Therefore, the conduction loss and switching loss of the main switch is reduced. In addition, the voltage gain is further increased by using turn ratio of a coupled inductor, and the reverse-recovery problem of the output diode is alleviated by the leakage inductor. Therefore, the proposed converter is suitable for fuel cell or renewable energy system.

3.4 ADVANTAGE SOF PROPOSED SYSTEM

- The conduction loss and switching loss of the main switch is reduced.
- The voltage gain is further increased by using turn ratio of a coupled inductor.
- Fuel cell applications.
- Renewable energy system

CHAPTER 4

OPERATING PRINCIPLE OF THE PROPOSED CONVERTER

4.1 OPERATING MODES

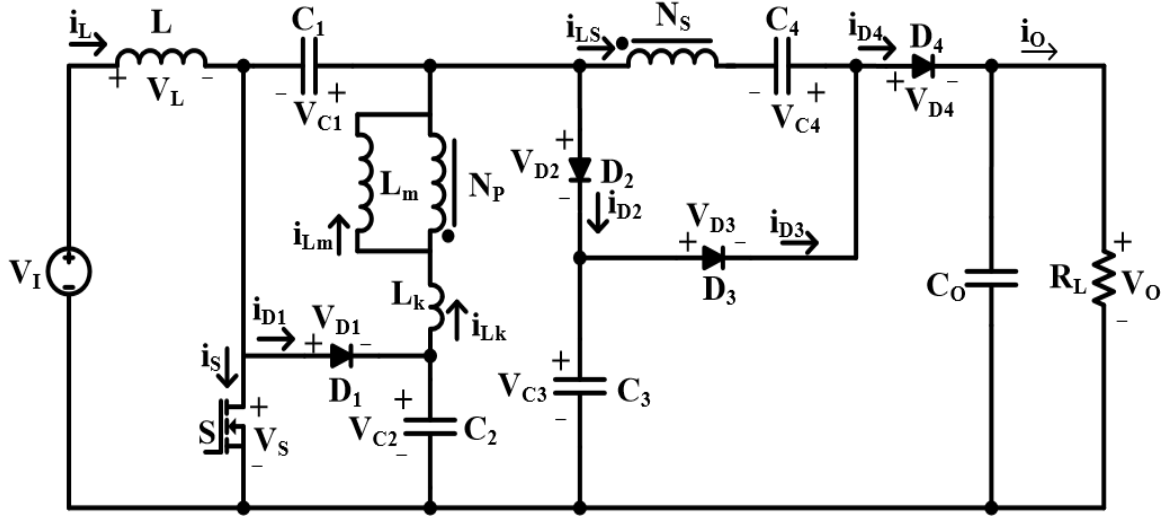


Fig. 4.1. The circuit configuration of the presented converter.

The structure of the proposed converter is shown in Fig. 1. The proposed converter consists of a power switch (S), four diodes, four capacitors, an inductor and a coupled-inductor. The diode D2 and capacitor C2 acts as the passive clamp circuit to recycle the energy stored in the leakage inductor (L_k) of the coupled-inductor. The secondary side of the coupled-inductor and capacitor C3 is a voltage-multiplier cell which increases the voltage conversion gain. In order to simplify the analysis, some assumptions are considered as bellow: 1-All the capacitors are large enough in order the voltage ripples of capacitors to be neglected to obtain the voltage gain in steady state operation. The current ripple of the inductors L and L_m are also neglected in voltage gain calculation. 2-All semiconductors are ideal. The operation of the proposed converter divided to five operation modes in a switching period. Fig. 2 shows the current flow paths of the different operation modes. The typical waveforms of the presented converter are depicted in Fig. 3. According to Fig. 4.1, the secondary side current of the coupled inductor can be written as follow: Since the inductor currents cannot change simultaneously, the secondary

side current of the coupled inductor cannot be change simultaneously too. The steady-state analysis of the presented converter is discussed as follows: Mode I [$t_0 < t < t_1$]:

In this interval, the switch S is turned ON. Diodes D1, D2 and D3 are turned OFF. The current of the secondary side of the coupled inductor flows through diode D4 to the output capacitor and the load. The inductors are magnetized and their currents increase linearly. This mode ends when the current of leakage inductor is equal to the current of magnetizing inductor which causes diodes D4 to turned off. By applying Kirchhoff Current Law (KCL), the switch current can be written as follow:

Mode II [$t_1 < t < t_2$]: This mode starts when the leakage current of the coupled-inductor reaches the current of magnetizing inductor. Therefore, the current of the secondary side of the coupled inductor reaches zero and diode D4 is turned OFF. Diode D3 is turned ON to conduct the current of the secondary side of the coupled-inductor. The magnetizing and leakage currents of the coupled inductor are increased linearly. The energy stored in capacitor C2 and C3 charge capacitor C1 and C4, respectively. The currents of capacitors can be written as follows:

In this mode, the output capacitor supplies the load. This mode ends when the power switch S is turned OFF. Mode III [$t_2 < t < t_3$]: At $t=t_2$, the power switch is turned OFF. The diodes D1, D2 and D3 are turned ON. The energy stored in the leakage inductance L_k is recycled via the passive clamp circuit, diode D2 and capacitor C3. Inductor L and the leakage inductor L_k are demagnetized in this mode. The output capacitor continues to provide the load power. This mode ends when the leakage current (i_{Lk}) equals with the magnetizing current (i_{Lm}) and diode D3 is turned OFF. By applying KCL on the proposed converter in this mode, the diode currents can be gained.

Mode IV [$t_3 < t < t_4$]: In this mode, diode D3 is turned OFF. Diode D4 is turned ON and the current of the secondary side of the coupled inductor flows to the output capacitor and the load. All inductors are demagnetized in this mode. Capacitor C2 is charged by inductor L and the power supply. Capacitor C4 is also discharged to the load. The capacitor current can be written in this mode as follows: This mode ends when diodes D1 and D2 are turned OFF. Mode V [$t_4 < t < t_5$]:

In this mode, when the diode D4 is still ON. Capacitors C1 and C4 are discharged to the load and capacitor C2 is charged by the coupled inductor. This mode ends when the power switch is turned ON in the next switching period. Equation (5) is also valid in this mode with the difference that the current of capacitor C3 is zero. The following equation is valid for the

inductors' currents. The time durations of modes I and III are very short. Therefore, these intervals are neglected in the analysis. According to Fig. 2(b), the below equations can be written for mode II. Where, n is N_P/N_S and V_{LK2} is the voltage across inductor L_K in the second mode. In mode IV, the voltages on the inductors can be expressed as below: Where, V_{LK5} is the voltage across inductor L_K in mode V. Substituting and simplifying the equations (14) and (15), we have: According Fig. 3, the slope of inductor current i_{Lk} is approximately zero. Therefore, in order to simplify the analysis, the inductor voltage V_{LK5} is assumed zero. In order to calculate V_{LK2} and V_{LK4} , the slope of inductor current i_{Lk} in modes II and IV can be used. This method is used in other articles too [23], [24]. By applying ampere-second balance principle on all capacitors, it can be proved that the average currents of diodes are equal to the output current I_O . In addition, by applying ampere-second balance principle on all capacitors C_2 and C_3 by using equations (3) and (5), the average current value of inductor L_m can be found as follow: As aforementioned, the average values of diode currents are equal to the output current. Therefore, according to Fig. 2, the following equation can be obtained. By applying KCL on Mode II, the following equation can be obtained: It's worth noting that as assumed The current ripple of the inductors L and L_m are also neglected in voltage gain calculation. The current stress of the switch and diode D_1 can be achieved as follows Where, f_S and R_L are the switching frequency and load resistance, respectively. Neglecting modes I and III and by applying volt-second balance principle on the inductor L_K , the following equation is obtained. Applying voltage-second balance principle on the inductors yields: As seen in this equation, the voltage gain of the coupled inductor based converters depends on the switching frequency, load resistance and the value of leakage inductor. However, it does not have significant effect on the voltage gain. The voltage gain of the proposed converter for different values of Q is depicted in Fig. 4. As shown in this picture, the effect of Q is very low and neglectable.

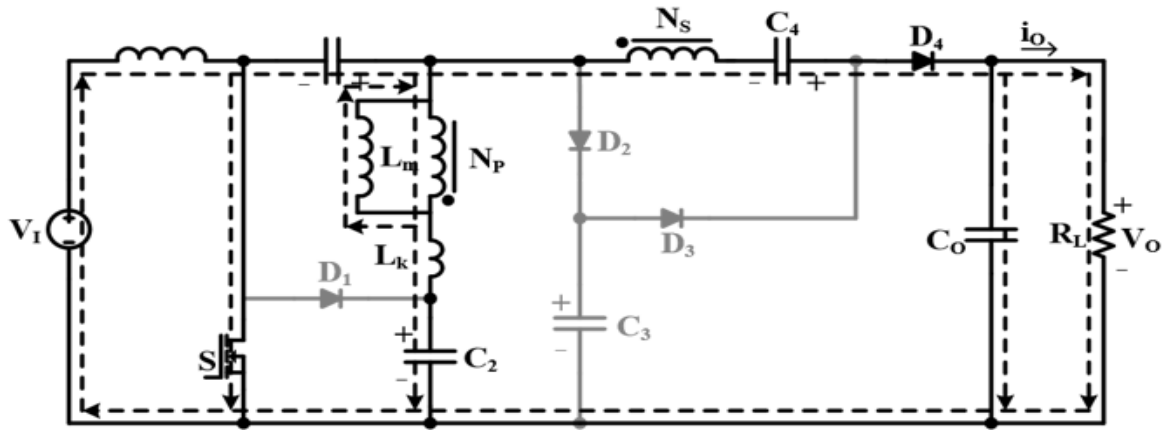


Fig 4.1 Mode 1 presented converter

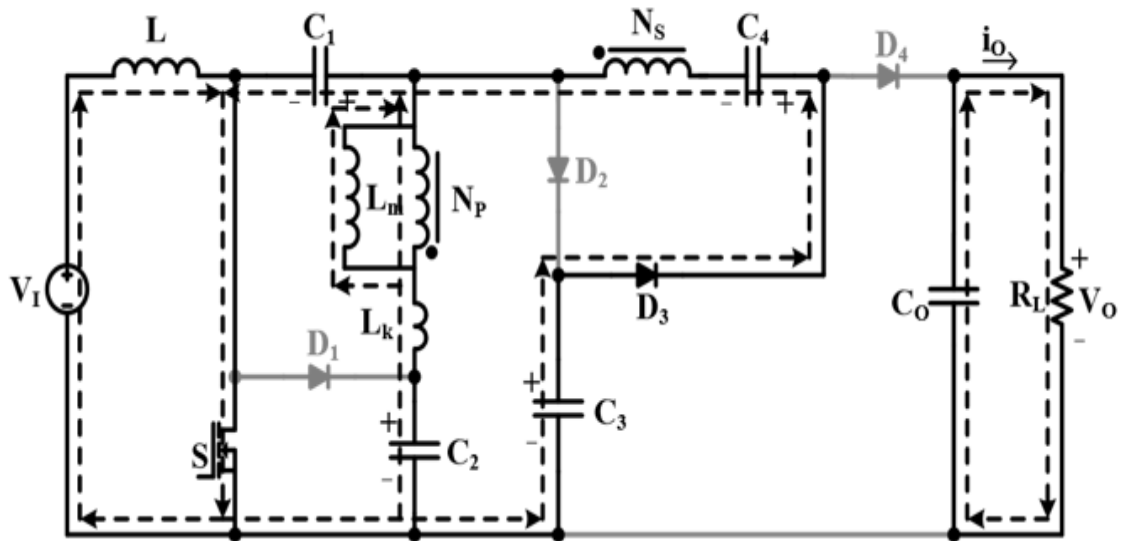


fig 4.2 Mode 2 presented converter

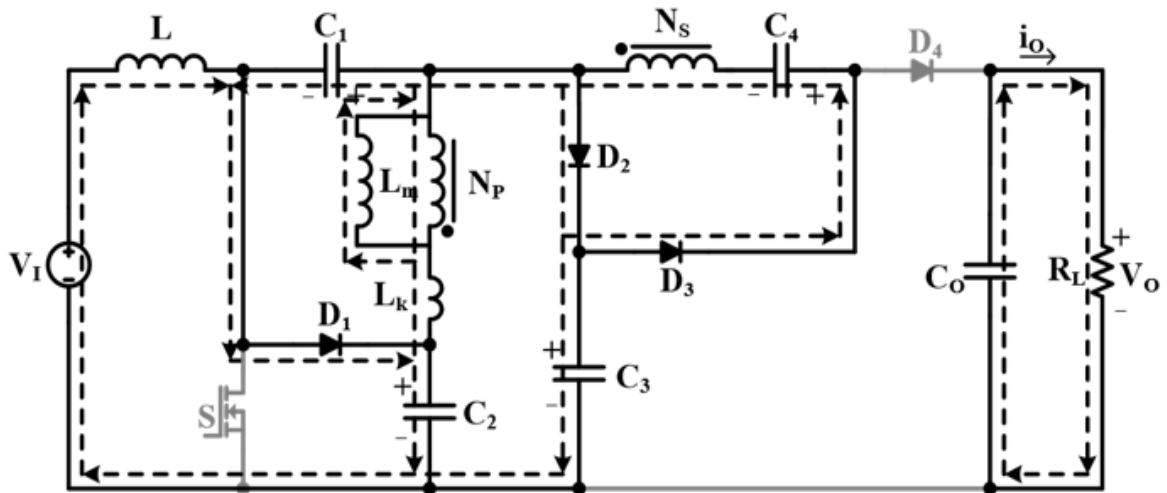


Fig 4.3 Mode 3 presented converter

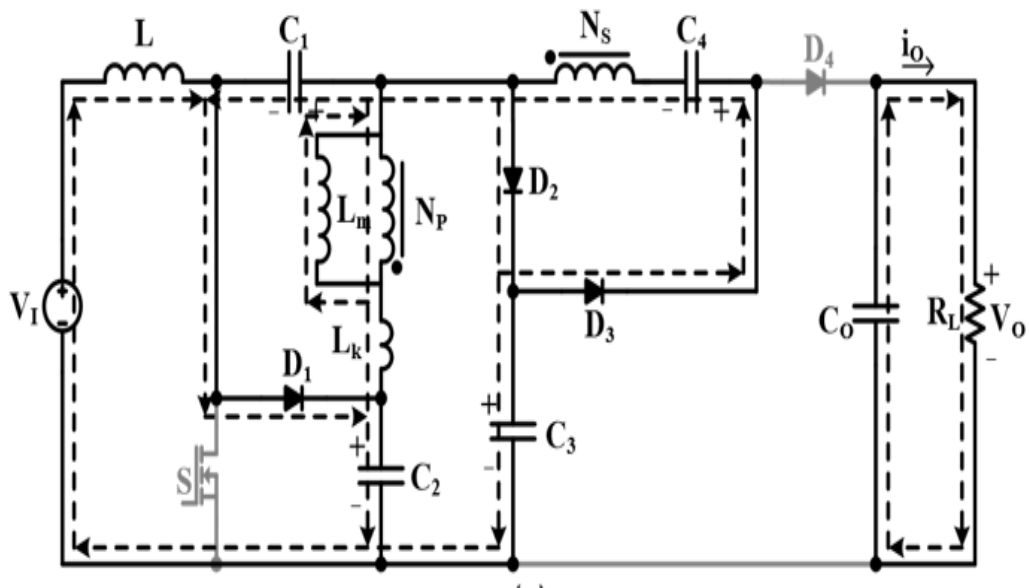


Fig 4.4 Mode 4 presented converter

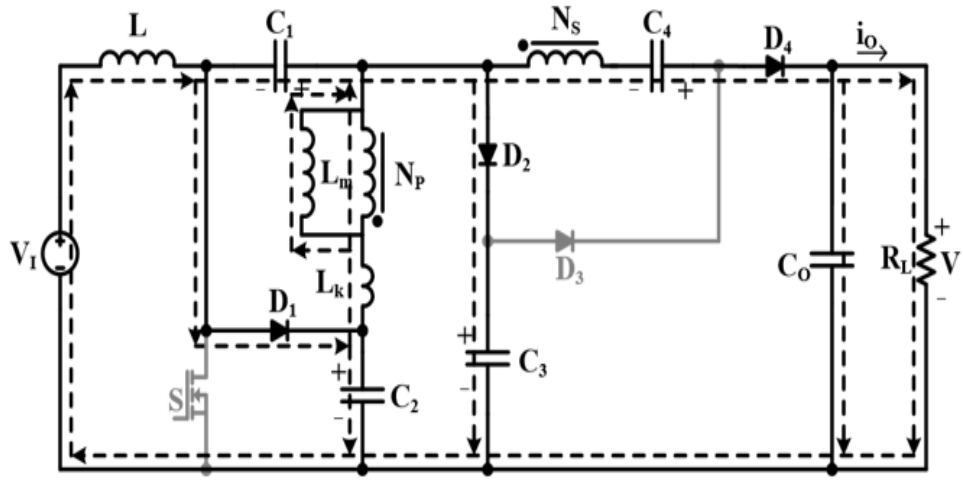


Fig 4.5 Mode 5 presented converter

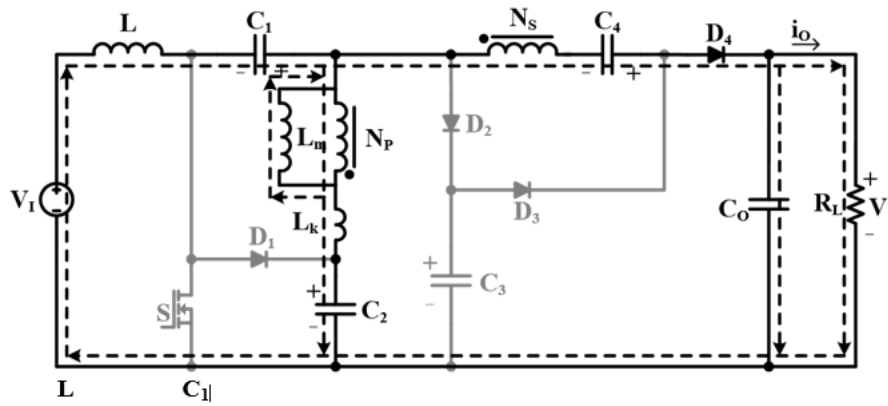


Fig 4.6 Mode 6 presented converter

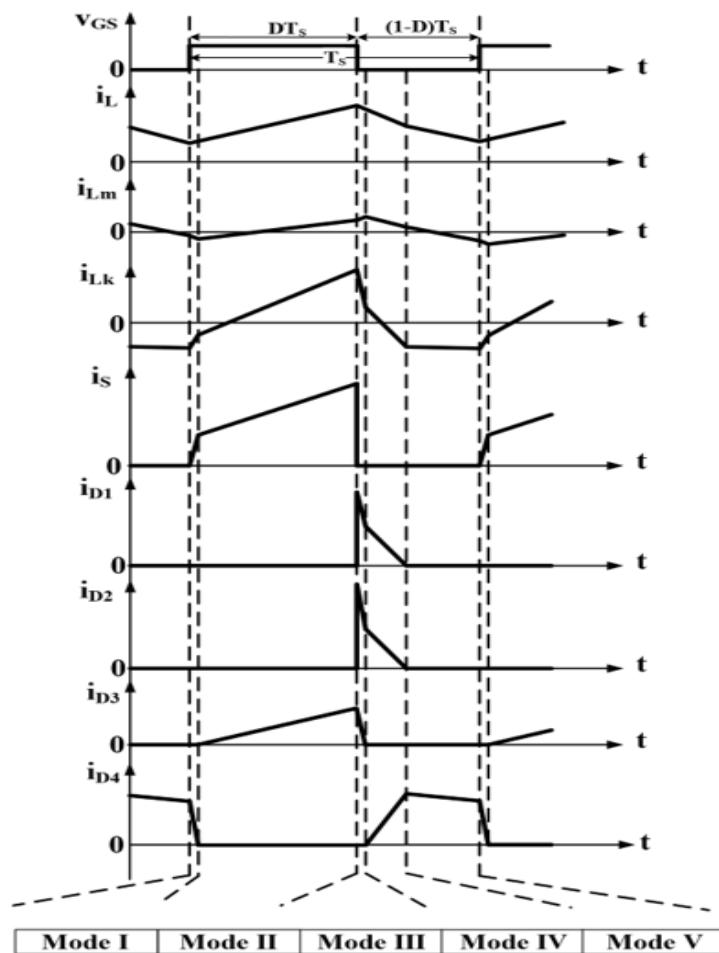


Fig 4.7 Modes Results

CHAPTER 5

PERFORMANCE COMPARISON OF THE PROPOSED CONVERTER WITH OTHER SIMILAR TOPOLOGIES

In this section, a comparative analysis is done between the proposed QRHGHE-SEPIC and its counterparts that have been recently published. For this purpose, typical performance indicators of step-up DC-DC converters including the static voltage gain, components count, input current ripple, voltage stress, soft switching condition, and efficiency are evaluated in Table I.

Fig. 10 shows a line chart of the voltage gain comparison of the converters referenced in Table I under a specified turns ratio $n = 2.5$ for duty range $0 < D < 1$. As it can be seen, only converters and have higher voltage gain than the proposed converter. However, the use of larger number of components, high input current ripple are the main disadvantages of these converters, which limits their applications for the RESs. Also, the converter in , which has identical voltage gain with the proposed converter, suffers from a high input current. In the other cases, just the presented QRHGHE-SEPIC can provide a higher voltage gain compared to the other converters while maintaining low current ripple, low components count and soft-switching performance for power switch as well as very low reverse recovery loss.

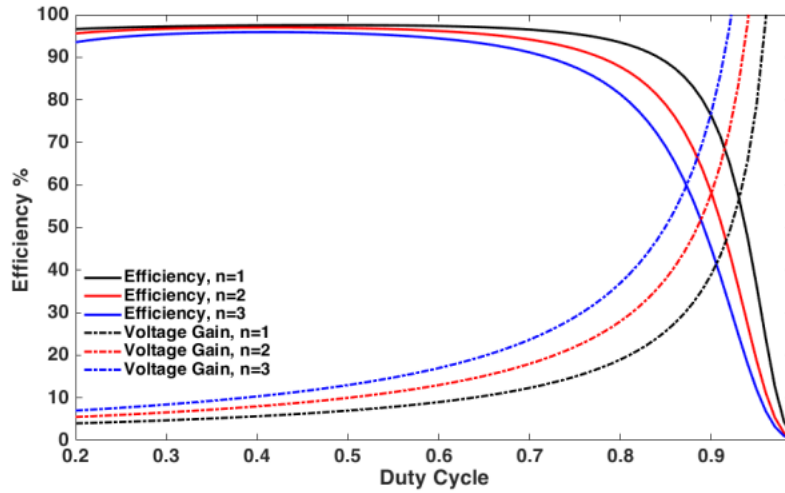


Fig. 5.1. The estimated efficiencies and voltage gains versus the duty cycle for different values of the turns ratios of the CI.

Furthermore, the normalized voltage stress rate across the power switch and the output diode of the converters that are given in Table I are compared under a specified condition ($n = 2.5$) and illustrated. As it can be observed, the proposed QRHGHE-SEPIC has the lowest level of voltage stress compared to the converters with continuous input current and soft-switching performance. This makes it possible for the designer to use switching components with lower parasitic components (i.e. MOSFETs with lower $R_{DS(on)}$ and diodes with lower forward drop voltage V_F), which alleviates the power losses.

Moreover, due to the soft-switching performance in the proposed converter, the switching loss is negligible. Hence, it is expected the proposed converter can provide an ultra-high voltage gain under high efficiency. For this purpose, a comparison of the theoretical efficiency in the same conditions of the switching frequency, input and output voltages, and output load (20 V to 200 V/100 W/ 60 kHz and $n=2$) are carried out and shown in Table I. The Parasitic components (resistors and forward drop voltage) are selected identical in different converters based on related datasheets. Regarding this table, the proposed circuit demonstrates the highest efficiency against the converters that have a good performance for the RES.

Finally, based on the aforementioned discussions, the suggested QRHGHE-SEPIC with high voltage gain at high efficiency can offer relatively better performance for the RES applications than other topologies shown in Table I.

5.1 DESIGN PROCEDURE OF THE ELEMENTS

As mentioned in section III, proper selection of the turns ratio and duty cycle are very important to reduce the power losses that occur in the components. Regarding Fig. 5, the minimum values of the switch current stress occur in the duty cycle range $0.4 < D < 0.7$. After selecting the appropriate duty cycle range, using (18), the turns ratio of the CL (n) can be obtained. B. Input (Lin) and Magnetizing (LM) Inductances To guarantee the best performance in RESs, it is necessary to draw continuous current with low ripple (CCM condition) from these sources. For this purpose, the input inductor Lin is designed as follows:

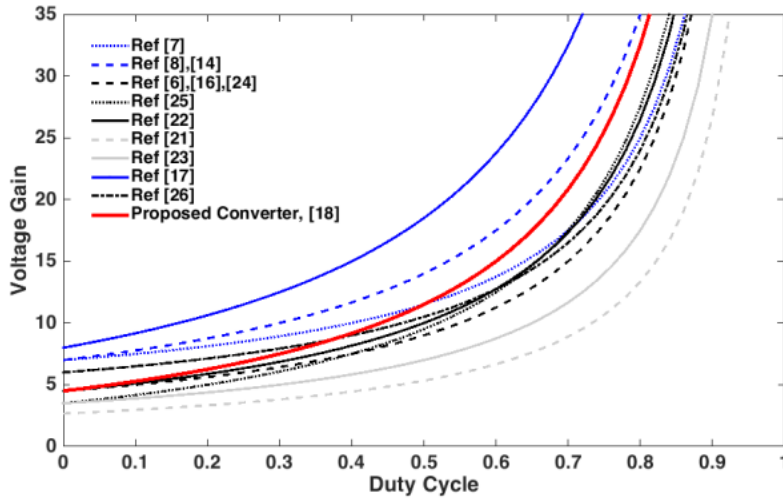


Fig 5.2 Voltage gain

TABLE I. PERFORMANCE COMPARISON OF DIFFERENT RELEVANT STEP-UP DC-DC CONVERTERS

Converter Topology	No. of Components	Voltage Gain	Input Current Ripple	Voltage Stress on Main Power Switch	Voltage Stress on Output Diodes	Soft-Switching (Switch)	Reverse Recovery Loss	Eff. 100Watt (60 kHz)
	S/D/C/CI+L/T							
[6]	1/3/4/1+1/10	$\frac{n+2}{(1-D)}$	Low	$\frac{V_o}{n+2}$	$\frac{(1+n)V_o}{n+2}$	Yes	Medium	96.9%
[7]	2/3/4/1+0/10	$\frac{2+n(2-D)}{(1-D)}$	High	$\frac{V_o}{2+n(2-D)}$	$\frac{(1+n)V_o}{2+n(2-D)}$	Yes	Low	97.5%
[8]	2/4/5/1+0/12	$\frac{2(1+n)}{(1-D)}$	High	$\frac{V_o}{2(1+n)}$	$2 \times \frac{V_o}{2}$	Yes	Very Low	97.5%
[14]	1/5/6/1+1/14	$\frac{2(1+n)}{(1-D)}$	Low	$\frac{V_o}{2(1+n)}$	$3 \times \frac{1+2n(1-D)V_o}{2(1+n)}$	Yes	Low	94%
[16]	1/4/4/1+0/10	$\frac{n+2}{(1-D)}$	High	$\frac{V_o}{n+2}$	$\frac{(1+n)V_o}{n+2}$	No	High	95.3%
[17]	1/6/6/1+0/14	$\frac{3+2n+nD}{(1-D)}$	High	$\frac{V_o}{3+2n+nD}$	$\frac{(1+n)V_o}{3+2n+nD}$	Yes	Low	92%
[18]	1/4/4/1+0/10	$\frac{2+n+nD}{(1-D)}$	High	$\frac{V_o}{2+n+nD}$	$\frac{(1+n)V_o}{2+n+nD}$	Yes	Low	95.8%
[21]	1/3/4/1+1/10	$\frac{(2n-1)}{(n-1)(1-D)}$	Low	$\frac{(n-1)V_o}{(2n-1)}$	$\frac{nV_o}{(2n-1)}$	Yes	Low	94.8%
[22]	1/4/5/1+1/12	$\frac{2+n+D}{(1-D)}$	Low	$\frac{V_o}{2+n+D}$	$\frac{(1+n)V_o}{2+n+D}$	Yes	Low	96%
[23]	1/3/4/1+1/10	$\frac{n+1}{(1-D)}$	Low	$\frac{V_o}{n+1}$	$\frac{nV_o}{n+1}$	Yes	Very Low	95.6%
[24]	1/3/4/1+1/10	$\frac{n+2}{(1-D)}$	Low	$\frac{V_o}{n+2}$	$\frac{(1+n)V_o}{n+2}$	Yes	Very Low	95.7%
[25]	1/4/5/1+1/12	$\frac{1+n(1+D)}{(1-D)}$	Low	$\frac{V_o}{1+n(1+D)}$	$\frac{(1+n)V_o}{1+n(1+D)}$	Yes	Very Low	95.5%
[26]	1/4/5/1+1/12	$\frac{1+D+n(2-D)}{(1-D)}$	Low	$\frac{V_o}{1+D+n(2-D)}$	$\frac{(1+n)V_o}{1+D+n(2-D)}$	Yes	Very Low	96.7%
Proposed Converter	1/4/5/1+1/12	$\frac{2+n+nD}{(1-D)}$	Low	$\frac{V_o}{2+n+nD}$	$\frac{(1+n)V_o}{2+n+nD}$	Yes	Very Low	97.3%

S=Switch, D=Diode, C=Capacitor, CI =Coupled-Inductor, L=inductor, T=Total Device Count, Eff=Efficiency

Using and assuming 20% current ripple, the minimum value of L_{in} can be obtained as follows. where f_s and R_L represent the switching frequency and the load As mentioned before the CI design is an important part of the converter analysis. The magnetizing inductor (L_M) of the CL can be designed by where ΔI_{LM} is the allowable current ripple. Due to the placement of the magnetizing inductor in the middle of the proposed circuit, L_M can also be designed with a larger current ripple. The design of the CI with a smaller amount of L_m reduces the leakage inductance, core volume, and also the power losses. By substituting and into the minimum value of L_M is obtained as: a Capacitors The proper value of converter capacitors can be determined based on their charge durations. The output capacitance is derived by using the following equation: where ΔV_{Co} is the ripple present in the output DC voltage, which is usually acceptable to be 1% of the output DC voltage. The suitable values capacitors C1, C3, C4 of the proposed converter where $\Delta\%$ represents the allowable voltage ripple. Also, the design of the capacitor C2 is based

on its maximum current as: where, d_2 is the conduction time interval of the diode D_2 , which is obtained as: Furthermore, regarding and operation analysis in Mode *III*, the QR duration is a function of the capacitors, C_1 , C_3 , and C_4 . Consequently, the value of these capacitors is also selected from the following equation: It is necessary to mention that the middle capacitors of the proposed converter are not performing any filtering effect. Therefore, their design can be done under larger allowable voltage ripples. Thus, choosing small values for these capacitors will not affect the output voltage fluctuation. This will give the designer more freedom in selecting the capacitors. Consequently, the simplest and most effective way for adjusting the proposed converter resonant frequency is by properly selecting the values of the capacitors C_1 , C_3 and C_4 using the resonant frequency (47).

CHAPTER 6

HARDWARE DISCRPTION

6.1 HARDWARE COMPONENTS

A SEPIC (Single-Ended Primary Inductor Converter) based DC-DC converter is a type of power converter commonly used in renewable energy systems. It allows the conversion of a DC voltage level into a different DC voltage level, while maintaining galvanic isolation between the input and output. To implement a high-gain, high-efficiency SEPIC based DC-DC converter, the following hardware components may be used:

Power MOSFETs: These are used as the main switching devices in the converter. They should have low on-state resistance, fast switching speed, and high breakdown voltage to ensure high efficiency and reliability.

Inductors: The converter requires two inductors - the primary inductor and the secondary inductor. The primary inductor is used to store energy during the switching cycle and transfer it to the output, while the secondary inductor is used to filter the output voltage and current.

Capacitors: Capacitors are used to store and filter energy in the converter. The input capacitor is used to smooth the input voltage, while the output capacitor is used to filter the output voltage.

Diodes: Diodes are used to rectify the AC voltage from the transformer into DC voltage.

Transformer: The transformer is used to provide galvanic isolation between the input and output of the converter. It also helps in voltage step-up or step-down.

Control circuit: The control circuit is responsible for controlling the switching frequency of the MOSFETs, to ensure efficient energy transfer and stable output voltage.

Heat sink: As the converter operates at high frequencies and high power levels, it generates a significant amount of heat. A heat sink is used to dissipate this heat and prevent overheating of the components.

6.2 Digital Signal Peripheral Interface Controller

DS PIC microcontrollers are commonly used for generating gate pulses in power electronic applications. The high-speed digital signal processing capabilities of the DS PIC microcontrollers make them ideal for controlling the timing and frequency of gate pulses. These microcontrollers can be programmed to generate pulse width modulation (PWM) signals, which are commonly used to control the power output of DC-DC converters, inverters, and other power electronic circuits. The DS PIC microcontrollers can also be programmed to generate various types of gate drive signals, including complementary, push-pull, and floating signals, depending on the specific application requirements. The ability of the DS PIC microcontrollers to generate precise and accurate gate pulses is essential for achieving optimal performance and efficiency in power electronic systems.

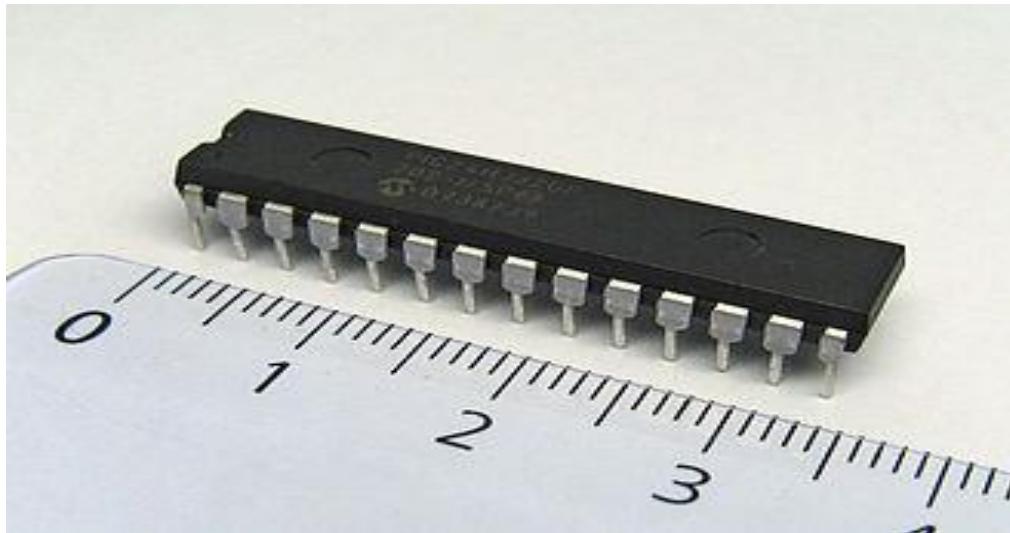


Fig 6.1 PIC microcontroller

6.3 MICROCONTROLLER CIRCUIT

A microcontroller can be used to implement the control circuit in a high-gain, high-efficiency SEPIC based DC-DC converter for renewable energy applications. The microcontroller can provide precise control of the switching frequency and duty cycle of the converter, which is critical for achieving high efficiency and stable output voltage. The microcontroller circuit can be designed to include the following components

Microcontroller: The microcontroller is the heart of the control circuit and is responsible for generating the pulse width modulation (PWM) signals to control the MOSFETs in the converter. It also reads input signals from sensors and adjusts the PWM signals accordingly to maintain the desired output voltage. **MOSFET drivers** are used to drive the high-side and low-side MOSFETs in the converter. They provide sufficient gate drive voltage and current to turn on and off the MOSFETs quickly and efficiently. **Current and voltage sensors:** Current and voltage sensors are used to measure the input and output current and voltage of the converter. The microcontroller uses this information to adjust the duty cycle of the PWM signals and maintain the desired output voltage. **Optocouplers:** Optocouplers are used to provide galvanic isolation between the high-voltage input and low-voltage control circuit of the converter. They help to prevent noise and voltage spikes from damaging the microcontroller. **Supporting components:** Supporting components such as resistors, capacitors, and inductors are used to filter the signals, protect the components, and control the current and voltage levels in the circuit. The microcontroller circuit can be programmed using a variety of programming languages such as C or assembly language. The code can be written and compiled on a computer, and then uploaded to the microcontroller using a programming tool such as a programmer or debugger. Once the microcontroller circuit is implemented, it can be tested and optimized for efficiency and stability. By adjusting the PWM signals and tuning the supporting components, the circuit can be optimized for the specific requirements of the renewable energy application.



Fig 6.2 Microcontroller circuit

6.4 DRIVER CIRCUIT

In a high-gain, high-efficiency SEPIC based DC-DC converter for renewable energy applications, the driver circuit is responsible for driving the MOSFETs in the converter. The driver circuit must be designed to provide fast, efficient switching of the MOSFETs, which is critical for achieving high efficiency and stable output voltage. The driver circuit can be designed to include the following components:

- MOSFETs:** The MOSFETs are the main switching devices in the converter, and they are responsible for regulating the output voltage. The MOSFETs must be selected based on their switching speed, on-state resistance, and maximum voltage and current ratings.
- Gate drivers:** Gate drivers are used to drive the MOSFETs, providing the necessary gate voltage and current to switch them on and off quickly and efficiently. The gate drivers must be capable of providing sufficient current to charge and discharge the gate capacitance of the MOSFETs quickly, which is important for minimizing switching losses.
- Input and output capacitors:** Input and output capacitors are used to filter the input and output signals, reducing noise and ripple on the voltage waveform. The capacitors must be selected based on their capacitance, voltage rating, and equivalent series resistance (ESR).
- Inductors:** Inductors are used to store energy in the converter, and they are essential for maintaining a stable output voltage.

The inductors must be selected based on their inductance, saturation current, and DC resistance. Supporting components: Supporting components such as resistors, diodes, and capacitors are used to filter the signals, protect the components, and control the current and voltage levels in the circuit. The driver circuit can be optimized for efficiency and stability by adjusting the values of the supporting components and tuning the gate drive signals. By using high-speed MOSFETs, fast gate drivers, and carefully selected inductors and capacitors, the driver circuit can achieve high efficiency and stable output voltage in a wide range of renewable energy applications.



Fig 6.3 Driver circuit

6.5 SEPIC CONVERTOR

A SEPIC (Single Ended Primary Inductance Converter) based DC-DC converter is a type of non-isolated converter that can be used to convert a DC voltage to a higher or lower DC voltage. In a high-gain, high-efficiency SEPIC based DC-DC converter for renewable energy applications, the SEPIC converter is used to step up or step down the voltage from the input source to the required output voltage level.

The SEPIC converter consists of a capacitor, an inductor, a diode, and two switches (usually MOSFETs) that are controlled by a pulse-width modulation (PWM) signal. The

capacitor and inductor are connected in series between the input and output of the converter, with one switch connected to the input and the other switch connected to the output. During the on-time of the PWM signal, the switch connected to the input is closed, and the switch connected to the output is open. The inductor charges up and stores energy from the input source, while the capacitor discharges and delivers energy to the output. During the off-time of the PWM signal, the switch connected to the input is open, and the switch connected to the output is closed. The inductor discharges and delivers energy to the output, while the capacitor charges up from the output voltage. The SEPIC converter can be optimized for high gain and efficiency by carefully selecting the values of the capacitor and inductor, and by tuning the PWM signal to achieve the desired output voltage and current. The efficiency of the converter can be improved by using high-speed MOSFETs, reducing switching losses, and by optimizing the values of the supporting components. In a renewable energy application, the SEPIC converter can be used to step up the voltage from a low-voltage solar panel or wind turbine to the required voltage level for charging a battery or powering an electrical load. By using a high-gain, high-efficiency SEPIC converter, the renewable energy source can be utilized more efficiently, reducing energy waste and improving the overall performance of the system.

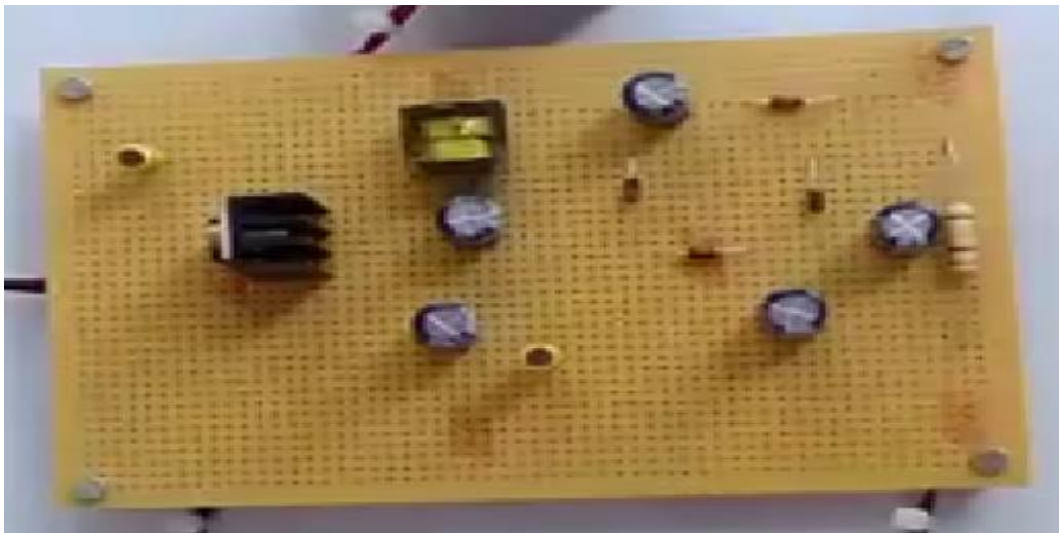


Fig 6.4 SEPIC convertor

6.6 HARDWARE KIT AND EXPLANATION

Here are the working details for a high gain, high efficiency SEPIC-based DC-DC converter for energy applications:

Input Voltage Regulation: The input voltage from the renewable energy source is regulated using a DC-DC converter. This converter converts the variable input voltage to a stable intermediate voltage that is used as the input to the SEPIC converter.

Coupled Inductor Operation: The coupled inductor module in the SEPIC converter is responsible for achieving high voltage gain. During operation, the input voltage is applied to the primary winding of the coupled inductor, and the output voltage is taken from the secondary winding. The magnetic coupling between the two windings allows the converter to step up or step down the input voltage.

Voltage Multiplier Operation: The voltage multiplier module is used in conjunction with the coupled inductor module to further increase the voltage gain of the converter. This module includes a voltage doubler or a voltage tripler circuit that multiplies the voltage at the output of the coupled inductor.

Synchronous Rectification: The synchronous rectifier module is responsible for reducing the losses associated with diode conduction in the converter. During operation, the high-speed switch in the synchronous rectifier module is controlled by a PWM signal to ensure that it only conducts when there is no voltage across it, resulting in minimal losses.

Resonant Circuit Operation: The resonant circuit module is used to implement a soft-switching technique in the converter, which reduces switching losses and improves efficiency. During operation, the resonant capacitor and inductor form a resonant circuit that helps to reduce the voltage across the high-speed switch in the synchronous rectifier module, allowing it to turn on and off more smoothly.

Output Voltage Regulation: The output voltage of the SEPIC converter is regulated using a feedback loop that compares the output voltage to a reference voltage. Any difference between the two voltages is used to adjust the duty cycle of the PWM signal, which in turn adjusts the output voltage to the desired level. Overall, a high gain, high efficiency SEPIC-based DC-DC converter for energy applications is designed to efficiently convert the variable input voltage

from renewable energy sources to a stable output voltage that can be used to power various devices and systems. The modules described above work together to achieve high efficiency and stability, while also reducing switching losses and minimizing the impact of diode conduction on overall performance.

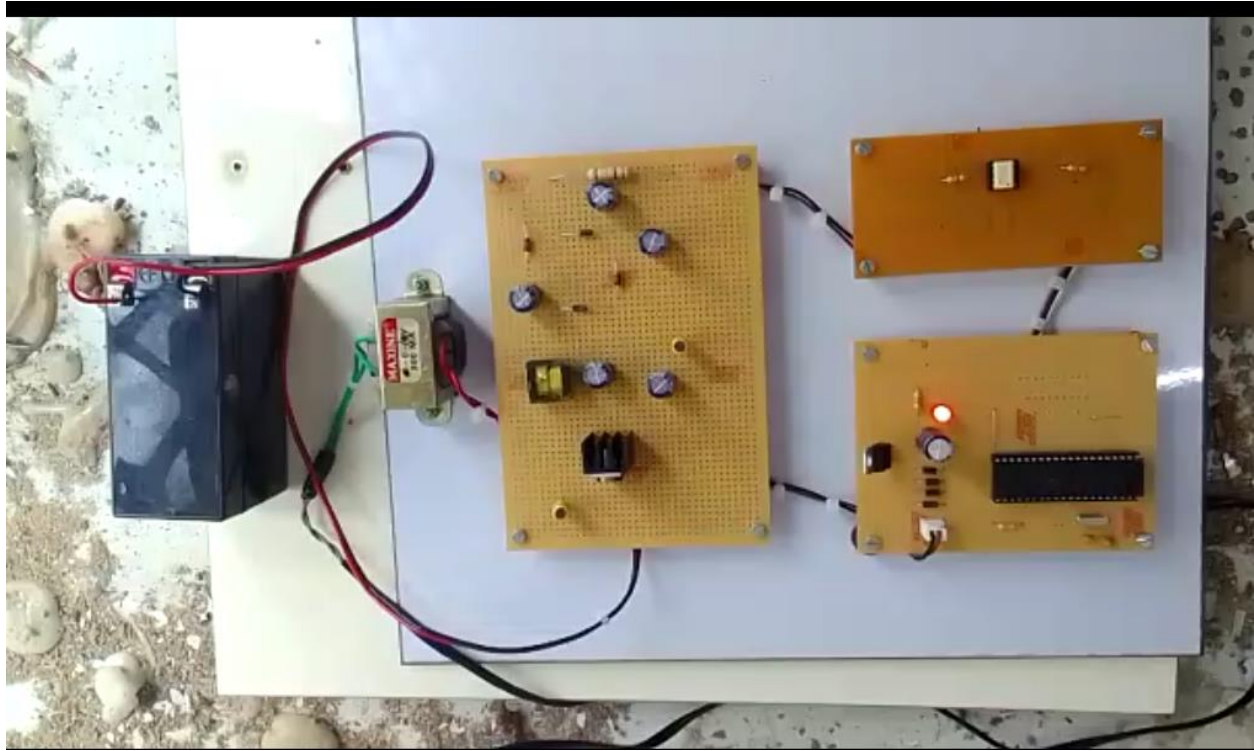


Fig 6.5 Hardware kit

CHAPTER 7

RESULT / DISCUSSION AND PERFORMANCE ANALYSIS

7.1 MATLAB DISCRIBTION

MATLAB is a fourth-generation programming language and a numerical computing environment created by MATHWORKS that enables users to manipulate matrices, plot functions and data, execute algorithms, create user interfaces, and integrate with software programs written in other programming languages such as C, C++, Java, and Fortran. Although MATLAB's primary purpose is for numerical computing, users have the option to access symbolic computing capabilities through the MUPAD symbolic engine, which is available in an optional toolbox. Furthermore, the software package SIMULINK enhances MATLAB's capabilities by providing users with graphical multi-domain simulation and Model-Based Design for dynamic and control systems.

7.2 ANALYSIS OF SEPIC CONVERTOR

In this paper, a novel sepic based high step-up DC-DC converter has been presented. High voltage gain, continuous input current and low voltage stress on the main power switch are the advantages of the proposed converter. The steady state analysis of the proposed converter under CCM condition has been discussed. The voltage gain, voltage stress of the main switch and d In order to prove the analysis and also the feasibility of the presented converter, a 220W prototype is implemented in the laboratory. The circuit specifications of the implemented prototype are summarized in Table II. The experimental results are provided below. The capacitor voltages, voltages across semiconductors and the current of inductors and semiconductors of the implemented proposed converter are shown, the output voltage is 1400V and its voltage ripple is very low. The below mentioned fig 6.1 displays the input mosfet gate pulse.

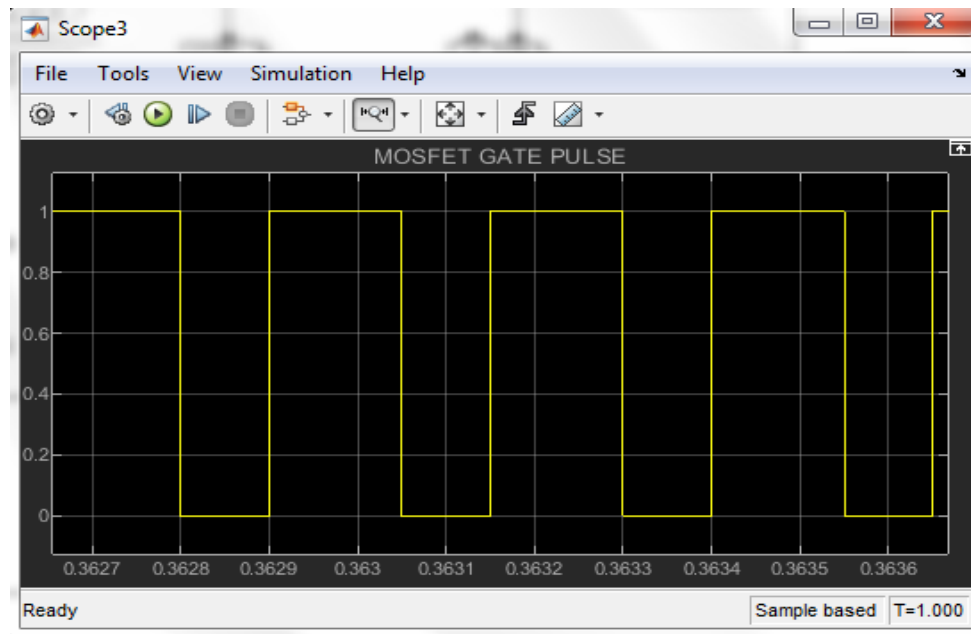


Fig 7.1 Gate trigger pulse

The voltage across other capacitors justifies the analysis of the article. The time per division in the results is 2.75. The current of inductors and semiconductors are shown in in this figure. The inductor current i_L is about 9A and its current ripple, which is input current ripple, is low. The currents of diodes and the power switch are also shown in this figure; the efficiency of the proposed converter under the output power of 220W is 94%.



Fig 7.2 Solar input source

The above mentioned fig 6.2 shows the input voltage value. We inputs 120 volts as input voltage. According to equations, the minimum value of the inductors in order the proposed converter operate in CCM under the output power of 220W can be obtained as follow: However, for these values, the proposed converter will operate near to DCM condition. Moreover, the input current ripple will be high. Therefore, the values of the inductors should be chosen away from these values. Using equation, for current ripple of about 20%, the value of inductor L can be obtained. The value of inductor L_m can also be chosen as well with the help of equation. Therefore, the values of inductors in the proposed converter are chosen $320\mu\text{H}$ and $100\mu\text{H}$. According to equation, the output voltage ripple with the output capacitor of $180\mu\text{F}$ will be lower than 0.1 V which is acceptable.

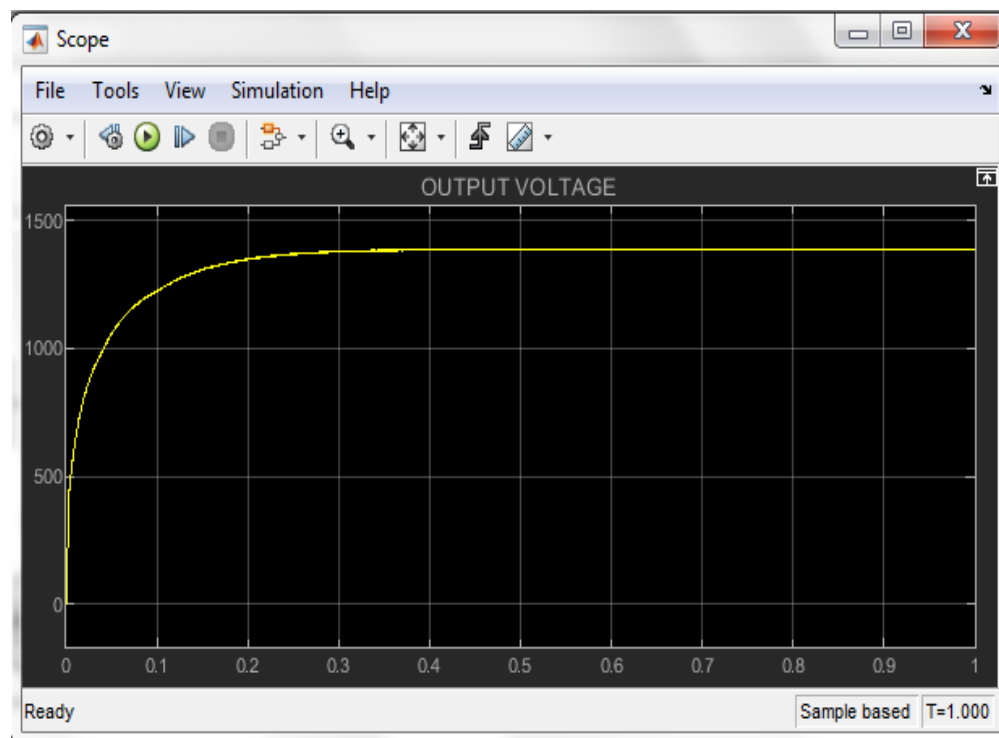


Fig 7.3 output voltage

The above mentioned figure 6.3 displays the output voltage result in graph. The voltage stress on the main switch and the diodes can be obtained according to equations and. The voltage stress on the main switch and the diodes justify the equations. The current stress on the main switch and the diodes can be achieved using equations the assumptions in theoretical analysis cause differences between the calculated and measured current stress on the main switch and

diode D4. Moreover, the currents i_{D1} and i_{D2} reach their peak values in very short time (mode III). According to the calculated voltage and current stresses on the semiconductors, the power switch and the diodes can be chosen. It's worth noting that the chosen components should tolerate more voltage and current. Besides the power switch should operate in its Safe Operation Area (SOA).

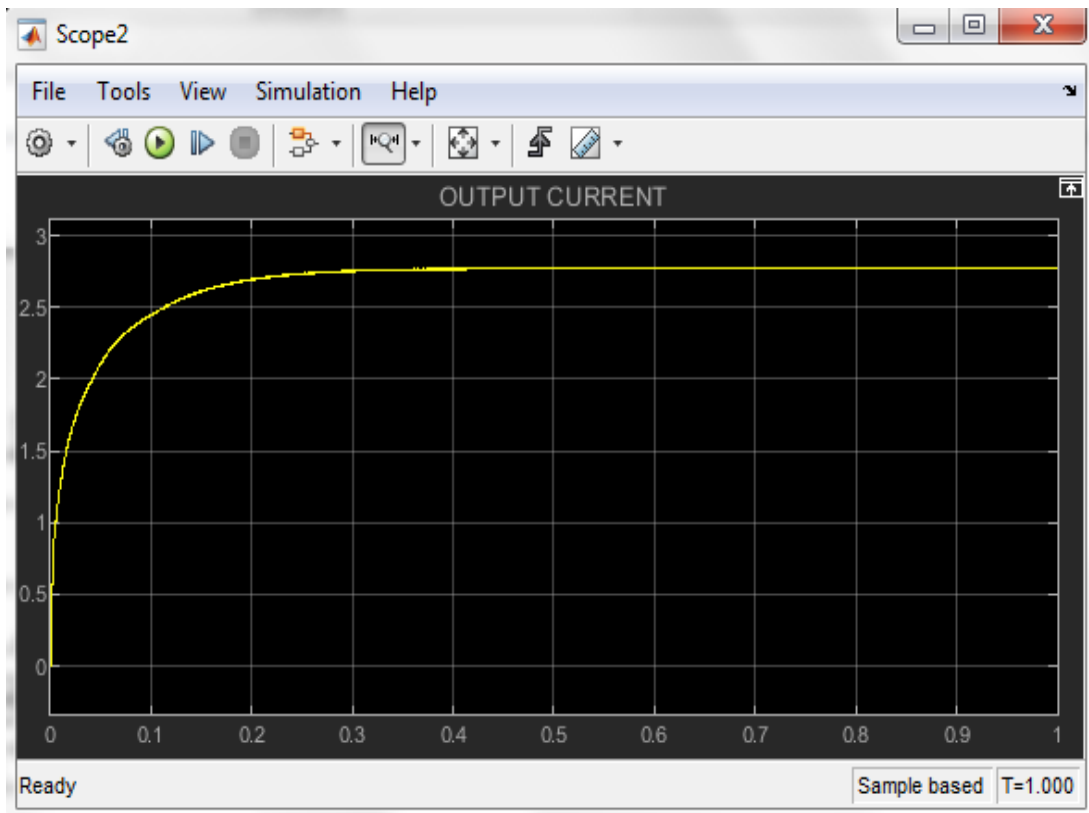


Fig 7.4 Output Current

The above mentioned figure 6.4 displays the out current value it increases from 0 to 2.75

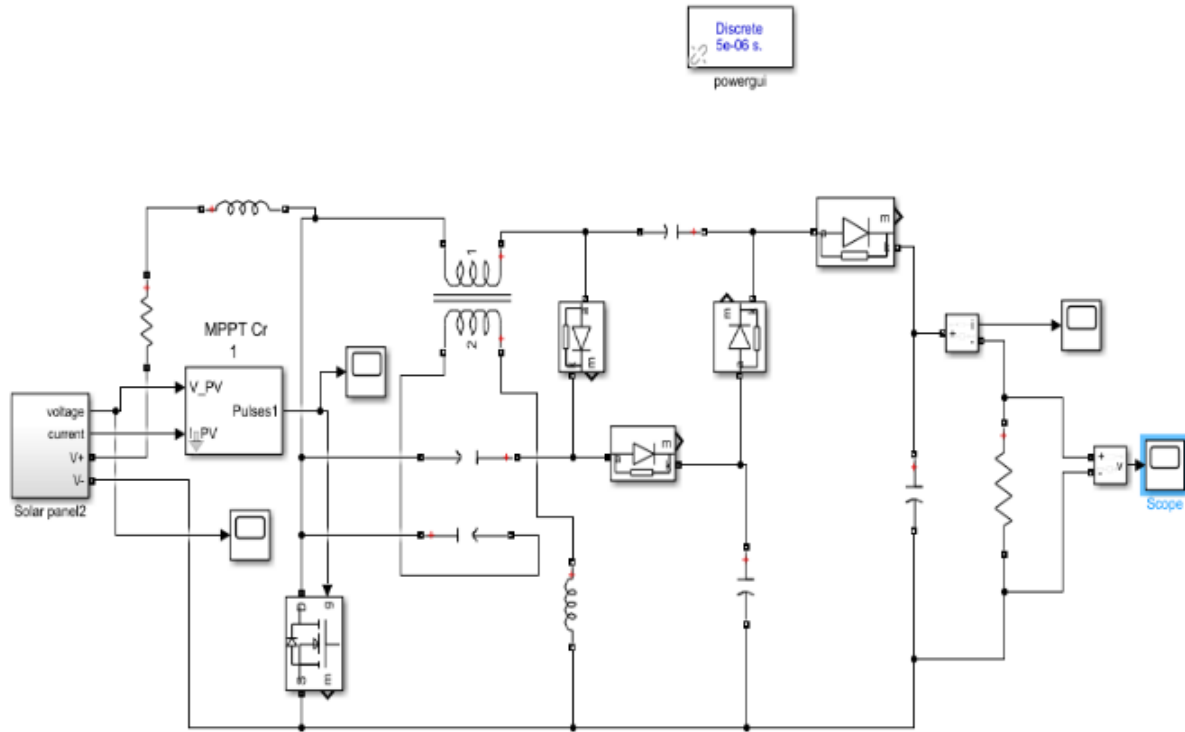


Fig 7.5 Whole circuit

diodes and other specification of the proposed converter has been compared with some other step-up DC-DC converters and the prominence of the proposed converter has been justified. Finally, the proposed converter has been implemented under the output power of 220W. The results verify the feasibility of the presented converter.

7.3 EXPERIMENTAL RESULTS

In order to prove the analysis and also the feasibility of the presented converter, a 220W prototype is implemented in the laboratory. The circuit specifications of the implemented prototype are summarized in Table II. The experimental results are provided below. The capacitor voltages, voltages across semiconductors and the current of inductors and semiconductors of the implemented proposed converter are shown, the output voltage is 300V and its voltage ripple is very low. The voltage across other capacitors justify the analysis of the article. The time per division in the results is 10. The current of inductors and semiconductors are shown in in this figure. As shown, the inductor current i_L is about 9A and its current ripple,

which is input current ripple, is low. The currents of diodes and the power switch is also shown in this figure. The efficiency curve is shown. As shown in this figure, the efficiency of the proposed converter under the output power of 220W is 94%. According to equations and, the minimum value of the inductors in order the proposed converter operate in CCM under the output power of 220W can be obtained as follow: However, for these values, the proposed converter will operate near to DCM condition. Moreover, the input current ripple will be high. Therefore, the values of the inductors should be chosen away from these values. Using equation, for current ripple of about 20%, the value of inductor L can be obtained. The value of inductor L_m can also be chosen as well with the help of equation Therefore, the values of inductors in the proposed converter are chosen 320 μ H and 100 μ H. According to equation, the output voltage ripple with the output capacitor of 180 μ F will be lower than 0.1 V which is acceptable. The voltage stress on the main switch and the diodes can be obtained according to equations. As shown, the voltage stress on the main switch and the diodes justify the equations. The current stress on the main switch and the diodes can be achieved using equations The assumptions in theoretical analysis causes differences between the calculated and measured current stress on the main switch and diode D4. Moreover, the currents i_{D1} and i_{D2} reach their peak values in very short time (mode III) which is not shown According to the calculated voltage and current stresses on the semiconductors, the power switch and the diodes can be chosen. It's worth noting that the chosen components should tolerate more voltage and current. Besides the power switch should operate in its Safe Operation Area (SOA).



Fig 8.6 Result of experiment

CHAPTER 8

CONCLUSION

A new single-switch SEPIC-based high step-up DC-DC converter is presented in this paper. High voltage gain, continuous input current with low ripple, low voltage spikes across the single power switch and diodes along soft-switching operation of all switching components are the traits of the proposed circuit. The steady-state analysis and design procedure have been presented in the CCM condition. The major performance indicators of the suggested converter have been compared with some other similar step-up converters and the merits of the QRHGHE-SEPIC have been justified. Experimental results from a 20 V-200 V /160 W laboratory prototype verified the validity of the design. The switching loss is significantly alleviated due to ZCS operation, which resulted

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