Voltage Multiplier Cell Applied to Modified SEPIC Converter For Renewable Applications

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Abstract : This paper introduces the use of the voltage multiplier technique applied to modified SEPIC converter in order to obtain high static for renewable applications. In the proposed converter topology, the commutation losses are reduced while achieving high static gain. The converter without magnetic coupling operates with hard switching and presents negative effect of the diode reverse recovery current while the converter with magnetic coupling reduces the negative effect of diode reverse recovery current. The operation principle, the design procedure and practical outcomes obtained from the implemented prototypes are presented for the converters with and without magnetic coupling.

IndexTerms - Voltage multiplier, SEPIC converter, Topology of SEPIC, Simulation Results

I. INTRODUCTION

The advancement and research of high static gain DC-DC converters is gaining importance due to requirement of this technology for several applications such as photovoltaic cells, low power wind turbine, embedded systems, portable electronic equipments and uninterruptible power systems. The converter should have low weight, volume, high power density and reduced losses.

The proposed converter is used in photovoltaic energy generation in grid-connected systems using the AC module or microinverter structure. In Europe, Japan and U.S., the PV grid-connected power system is recently becoming a fast growing segment. The output voltage of PV array is low, in order to obtain a high output voltage the PV series connected configuration is used. Though, series connected PV array is the conventional solution sometimes the generated power of the PV array is reduced due to the shadows, caused by clouds, trees, neighbor's house and even power line cables. In such case PV parallel connected configuration is more efficient.

A Single-ended primary-inductor converter (SEPIC) is a boost converter followed by a buck-boost converter, it has benefit of having non-inverted output, using a series capacitor to couple energy from the input.

Many techniques were considered in order to increase static gain of the DC-DC converter for the achievement of high efficiency and high power density solutions. The techniques based on boost topology with an additional technique associated. The main techniques used are voltage multiplier cells, switched inductors, switched capacitors, coupled inductor, and inductor magnetic coupling. In the proposed converter topology, the voltage multiplier technique is applied to modified SEPIC converter with magnetic coupling. The SEPIC converter with voltage multiplier cell is proposed to extend the voltage gain, reduce the switch voltage stress, improve the output diode reverse recovery problem. By using the voltage multiplier cell the circuit structure is simplified. The voltage multiplier cell is composed of a capacitor, two diodes, and the secondary winding of the inductor. Furthermore, zero- current-switching (ZCS) turn-ON soft-switching performance for the switches is realized, which reduces the switching losses and electromagnetic interference (EMI) noises.

II. SEPIC CONVERTER

2.1 Classical SEPIC Converter

The circuit diagram of the classical SEPIC converter is shown in Fig.1. In the classical SEPIC converter the static gain can be step -up and step -down which is very significant for different ranges of input voltage and the total of input and output voltages is equal to voltage switch of SEPIC converter, because of this reason static gain is less than step-up converter. For this reason, the SEPIC converter is improved to increase the static gain.

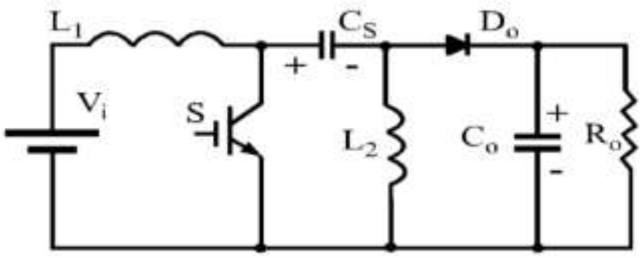

Figure 1:Conventional SEPIC converter

2.2 Modified SEPIC Converter Without Magnetic Coupling

The modified SEPIC converter without magnetic coupling is shown in Fig.2. The circuit diagram is modified with the addition of diode D_M and the capacitor C_M. Many features of the classical SEPIC converter are changed with the converter without magnetic coupling.

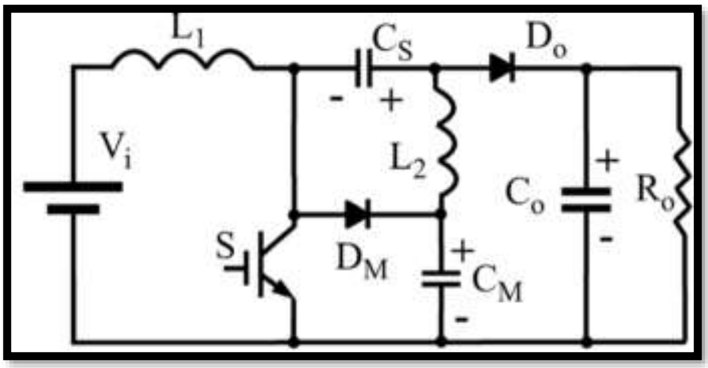

Figure 2:Modified SEPIC converter without magnetic coupling

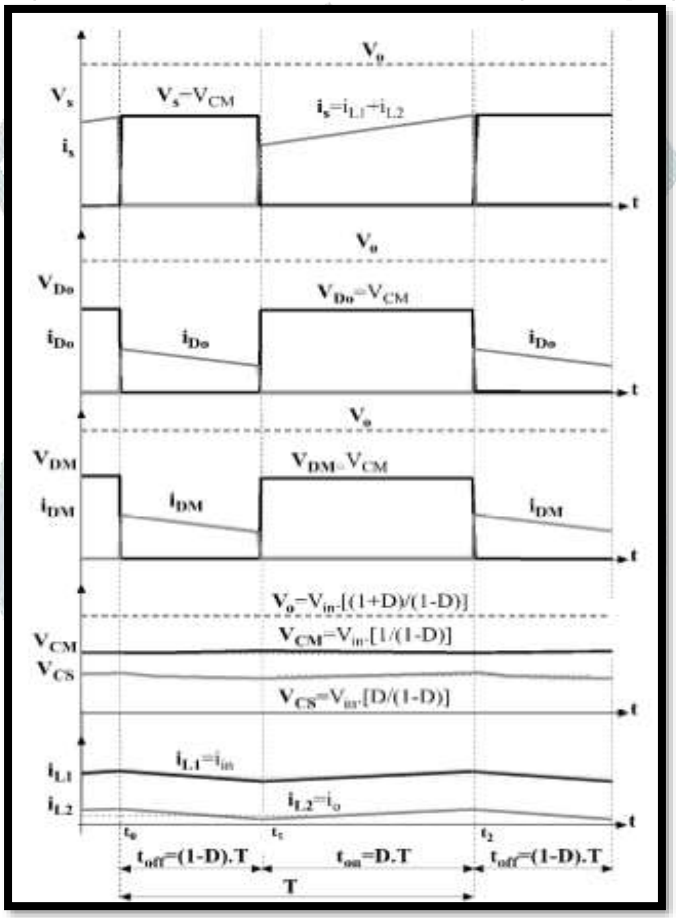

Figure 3:Theoretical waveforms

Figure.3 represents the theoretical waveforms for the modified SEPIC converter without magnetic coupling.

III. SEPIC CONVERTER WITH MAGNETIC COUPLING AND VOLTAGE MULTIPLIER CELL

3.1 Power Circuit with Magnetic Coupling

The converter without magnetic coupling can operate with the double of the static gain of the classical boost converter for a high duty cycle. But, a very high static gain is required in some applications. A very high static gain is achieved by the converter with magnetic coupling. The modified SEPIC converter with magnetic coupling is shown in Fig.4. The circuit diagram with magnetic coupling includes the secondary winding in the inductor L_2 which increases the output voltage by the transformer turns ratio (n). The modified SEPIC converter with magnetic coupling presents a very high static gain and reduced switch voltage and duty cycle.

Although, the present converter circuit increases the output voltage it has a problem of overvoltage at the output diode D_o which occurs due to transformer leakage inductance L_2. The problem of overvoltage cannot be controlled using classical snubbers or dissipative clamping.

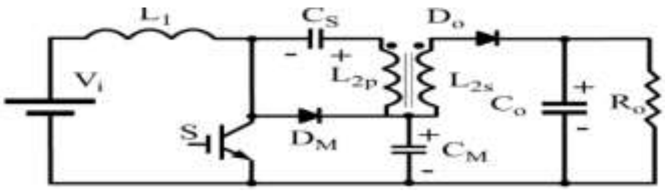

Figure 4:Modified SEPIC converter with magnetic coupling

4.2 Proposed converter

The modified SEPIC converter with magnetic coupling has the problem of overvoltage at the output diode due to the presence of coupling winding L_2 leakage inductance. There are various solutions to achieve high static gain based on the integration of SEPIC converter with boost and flyback DC-DC converters. But, the integration of SEPIC with boost and flyback increases the complexity of the converter with more than one controlled switch and command circuit. A simple solution is the integration of modified SEPIC converter with voltage multiplier cell which gives excellent performance. The problem of overvoltage and achieving a high static gain can be solved by using voltage multiplier which is composed of diode D_{M2} and capacitor C_{S2}. The voltage multiplier is placed at secondary side which is shown in Fig.5. By the inclusion of voltage multiplier in the circuit the converter static gain is increased, the voltage across the output diode D_o becomes lower than the output voltage and the energy which is stored in the leakage inductance is transferred to the output.

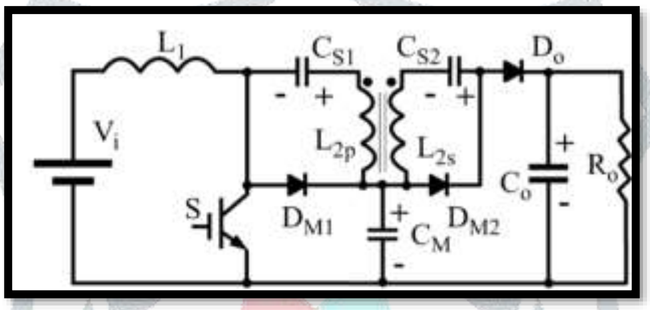

Figure 5:Modified SEPIC converter with magnetic coupling using voltage multiplier cell

Thus, the voltage multiplier cell formed by the diode D_2 and capacitor C_{S2} is a non-dissipative clamping circuit for the output diode.

Figure.6 represents theoretical waveforms for modified SEPIC converter with magnetic coupling using voltage multiplier cell.

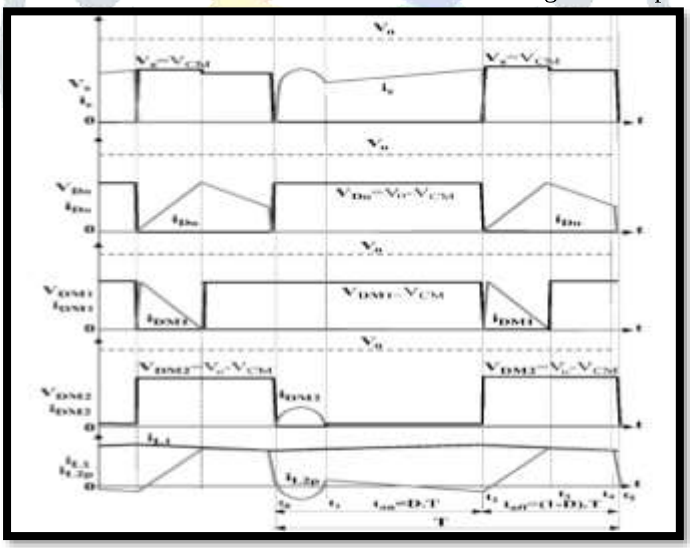

Figure 6:Main theoretical waveforms of the modified SEPIC converter with magnetic coupling using voltage multiplier cell

IV. SEPIC CONVERTER SIMULATION RESULTS

4.1 Classical SEPIC Converter

Table 4.1 Results of classical SEPIC converter

parameters	Output values
Input Voltage(Vi)	15V
Output Voltage(Vo)	30V
Output Power(Po)	100W
Static Gain(q)	2

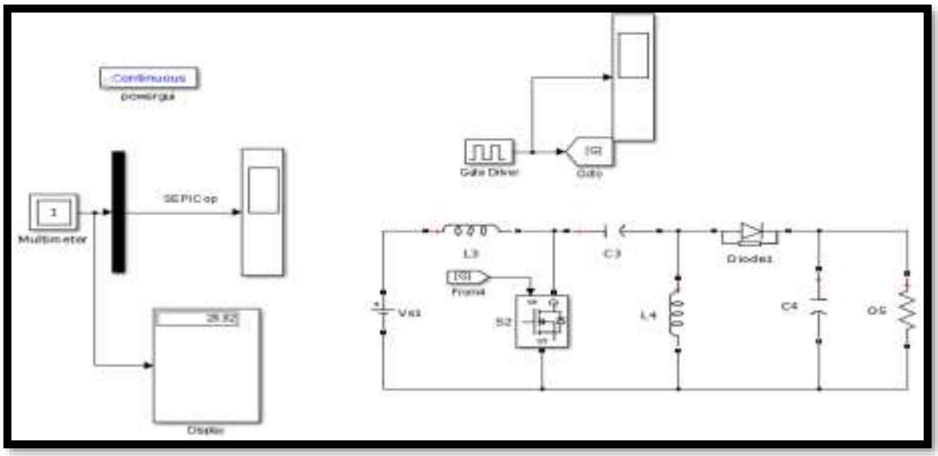

Figure 7:Simulation of conventional SEPIC converter

Fig.7 shows the classical SEPIC converter topology with input voltage of 15V and output is approximately 30V.

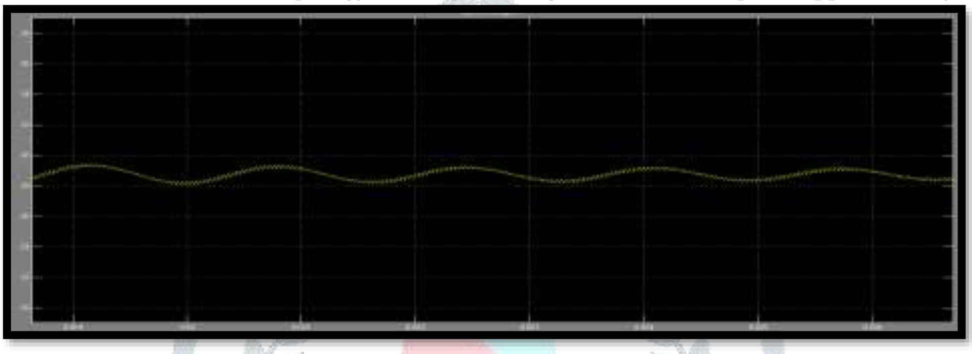

Figure 8:Simulation result of conventional SEPIC converter

Fig.8 show output voltage which is a sum of voltage across diode C_M and voltage across switch S. Simulation result of classical SEPIC converter give gain of 2.

4.2 Modified SEPIC Converter without magnetic coupling

Table 4.2 Results of Modified SEPIC converter without magnetic coupling

parameters	Output values
Input Voltage(Vi)	15V
Output Voltage(Vo)	150V
Output Power(Po)	100W
Static Gain(q)	10

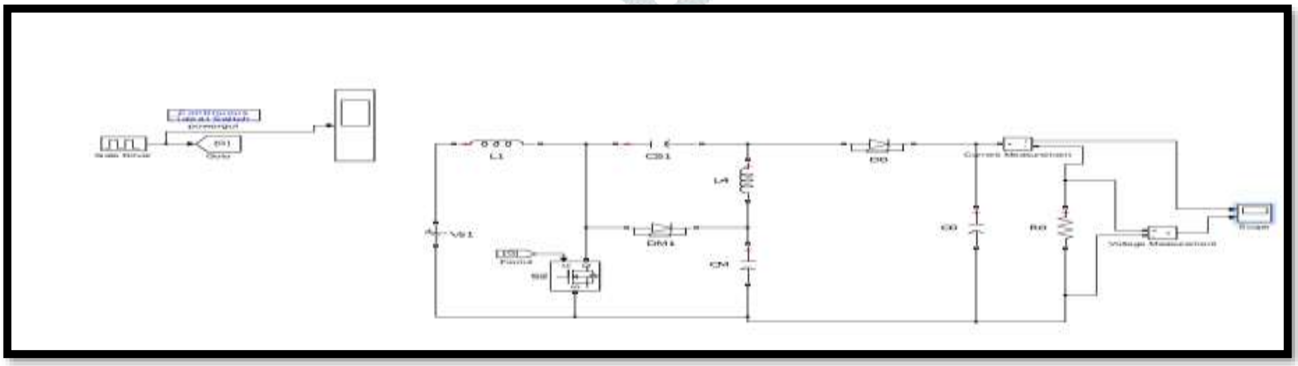

Figure 9:Simulation of Modified SEPIC converter without magnetic coupling

Fig.9 represents the modified SEPIC converter without magnetic coupling with the input voltage of 15V and output voltage approximately 150V.

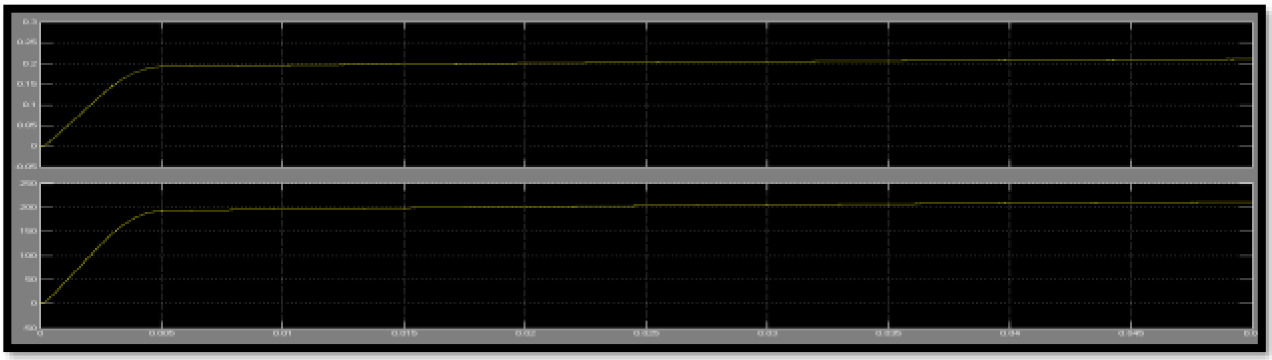

Figure 10:Simulation result of Modified SEPIC converter without magnetic coupling

Fig.10 represents the simulation result of modified SEPIC converter without magnetic coupling. The gain of the converter is 10.

4.3 Modified SEPIC Converter with magnetic coupling

Table 4.3 Results of Modified SEPIC converter with magnetic coupling

Parameters	Output values
Input Voltage(Vi)	15V
Output Voltage(Vo)	300V
Output Power(Po)	100W
Static Gain(q)	20

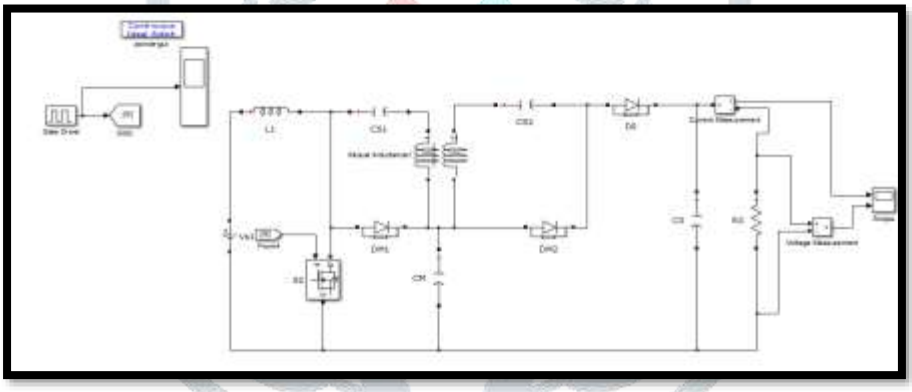

Figure 11:Simulation of Modified SEPIC converter with magnetic coupling using voltage multiplier cell

Fig.11 represents the modified SEPIC converter with magnetic coupling, the input voltage is 15V and output is approximately 300V.

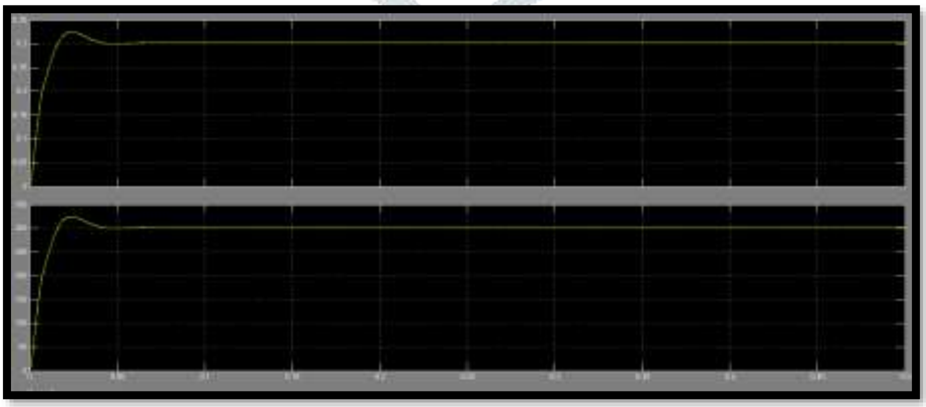

Figure 12:Simulation result of Modified SEPIC converter with magnetic coupling using voltage multiplier cell

Fig.12 represents the simulation result of modified SEPIC converter with magnetic coupling. The gain of the converter is 20.

V. CONCLUSION

This paper has introduced the use of modified SEPIC converter with magnetic coupling using voltage multiplier cell, which offers a method to increase the voltage gain with coupled inductor. The increase in voltage gain improves the converter efficiency, the problem of overvoltage is reduced. The proposed topology is very important in reducing the reverse recovery current of the output diode and the commutation losses are reduced.

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