Research Paper

HIGH STATIC GAIN FOR SOLAR APPLICATION USING MODIFIED SEPIC CONVERTER

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ABSTRACT

High static gain DC-DC converters are nowadays an important research focus due to the crescent demand of this technology for some applications as renewable energy sources, fuel-cells, low power wind turbine, photovoltaic(PV) modules, embedded systems, portable electronic equipment, uninterrupted power supply, battery powered systems and others applications supplied by low DC voltage energy sources. High step-up ratio is necessary when some loads operate with and DC or AC peak voltage higher than ten times the input source voltage. The modified SEPIC converter with magnetic coupling, gives a very high static gain solution with minimizing the commutation losses, voltage stress and reverse recovery problem. And also gives a high efficiency as compared to modified SEPIC converter without magnetic coupling.

KEY WORDS: SEPIC Converter, Solar, DC-DC converters

I. INTRODUCTION

High static gain DC-DC converters are nowadays an important research focus due to the crescent demand of this technology for some applications as renewable energy sources, fuel-cells, low power wind turbine, photovoltaic(PV) modules, embedded systems, portable electronic equipments, uninterrupted power supply, battery powered systems and others applications supplied by low DC voltage energy sources. High step-up ratio is necessary when some loads operate with and DC or AC peak voltage higher than ten times the input source voltage. Some of the requirements are necessary in this application such as reduced losses, high power density, low weight, and volume. An application where the proposed converters can be applied is the photovoltaic energy generation in grid-connected systems using the ac module or micro inverter structure. The usually in high-power grid-connected photovoltaic generation PV modules are connected in series in order to obtain the DC voltage level necessary for the inverter operation and energy can be transferred to the grid with low-current harmonic distortion. However, a common problem in this structure is the power losses due to the centralized maximum power point tracking (MPPT), mismatch losses among the PV modules, and generation reduction due to a partial shading of the series-connected PV modules. These problems are rectified by the Multistring structure where reduced strings are connected with dc–dc converters with the MPPT algorithm and the output of these dc–dc converters are connected to the inverter input.

In the home or domestic based application, most research is focused on the module-integrated converters where energy generated by the PV module is transferred to the grid through the high gain converter they can integrated with the PV module system. Some of the main advantages of this PV generation structure are the modularity, allowing an easy increase of the installed power, the individual MPPT and reduction of the partial shading and panel mismatching effects, thus improving the energy-harvesting capability. However, Efficiency improvement, cost reduction, and the reliable operation throughout the module lifetime is some design challenges in ac module system. High step-up ratio can is necessary for the implementation of the first power stage, the usual solution is the use of isolated dc–dc converters. The transformer turns ratio allows us to increase the converter static gain. However, the isolated solution presents some problems as the efficiency reduction due to the power transformer losses and intrinsic parameters as the leakage inductance. A static gain around to q=5 is a limited value for the applications considered in this work and this range is considered as a standard static-gain in this project. A converter operating with static gain equal or higher q=10 is considered a high-static gain solution and an operation with static gain higher than q=20 is considered a very high static gain solution in this project.

II. PROBLEM FORMULATION

There are two techniques used to understand the high static gain that is one as Power circuit without magnetic coupling and another as Power circuit with magnetic coupling. In Power circuit without magnetic coupling, the input voltage is equal to 15V, output power equal to 100W, output voltage as 150V and Efficiency as 91.9%. Due to the absence of voltage multiplier at the secondary side it causes a over voltage across output diode.

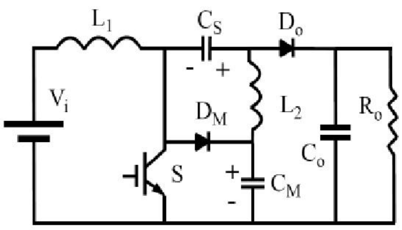

Fig. 1. Modified SEPIC converter without magnetic coupling.

So to overcome this problem we go through the Power circuit with magnetic coupling, where the input voltage will be same i. e. 15V, the output power is 100W, output voltage is equal to 300V, and Efficiency is about to 92.2%. and the problem related to output diode i. e. over voltage is also solved by using voltage multiplier at secondary side with a capacitor having non-dissipative clamping.

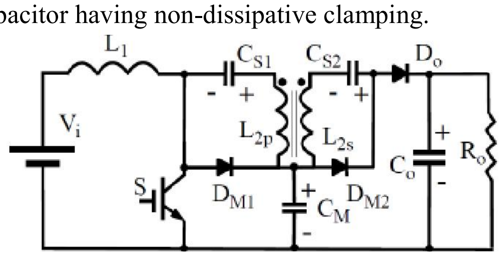

Fig. 2. Proposed converter - Modified SEPIC converter with magnetic coupling and output diode voltage clamping.

III. OBJECTIVE

The objective of this work is to overcome the drawbacks of power circuit without magnetic coupling such as follows: To maintain the converter performance with a duty cycle close to D=0.85.To increases the static gain without increasing the duty cycle. To maintain the switch voltage a secondary winding L_2 Inductor is used, which increases the output voltage by the transformer turns ratio (n).To overcome the over voltage problem a voltage multiplier is used.

IV. METHODOLOGY

The modified SEPIC converter without magnetic coupling can operate with the double of the static gain of the classical boost converter for a high duty-cycle. However, a very high static gain is necessary in some applications. A practical limitation for the modified SEPIC converter in order to maintain the converter performance is a duty-cycle close to D=0.85, resulting in a static gain equal to q=12.3. A simple solution to increase the static gain without increases the duty-cycle and the switch voltage is to include a secondary winding in the L2 inductor. The L2 inductor operation is similar to a buck-boost inductor and a secondary winding can increases the output voltage by the transformer turns ratio (n).

Figure 3 shows this circuit alternative. However, this converter structure presents the problem of overvoltage at the output diode Do due to the existence of the transformer L2 leakage inductance. The energy stored in the leakage inductance due to the reverse recovery current of the output diode results in voltage ring and high reverse voltage at the diode Do. This overvoltage is not easily controlled with classical snubbers or dissipative clamping.

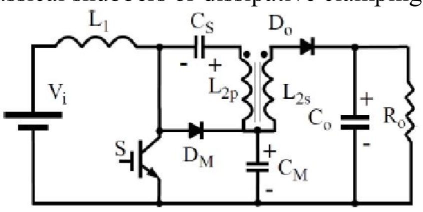

Fig. 3. Modified SEPIC converter with magnetic coupling.

A simple solution for this problem is the inclusion of a voltage multiplier at the secondary side as presented in Fig. 4. This voltage multiplier increases the converter static gain, the voltage across the output diode is reduced to a value lower than the output voltage and the energy stored in the leakage inductance is transferred to the output. Therefore the secondary voltage multiplier composed by the diode DM2 and capacitor CS2 is also a non-dissipative clamping circuit for the output diode. The circuit presented in Fig. 4 is the power circuit studied in this project.

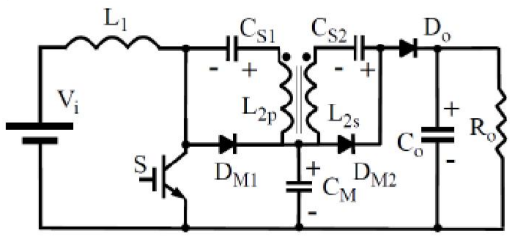

Fig. 4. Proposed converter - Modified SEPIC converter with magnetic coupling and output diode voltage clamping.

The continuous conduction mode operation of the modified SEPIC converter with magnetic coupling and output diode clamping presents five operation stages. All capacitors are considered as a voltage source for the theoretical analysis.

1) First Stage ([t0, t1] Fig. 5) – The power switch S is conducting and the input inductor L1 stores energy. The capacitor CS2 is charged by the secondary winding L2S and diode DM2. The leakage inductance limits the current and the energy transference occurs in a resonant way. The output diode is blocked and the maximum diode voltage is equal to (Vo-VCM). At the instant t1 the energy transference to the capacitor CS2 is finished and the diode DM2 is blocked.

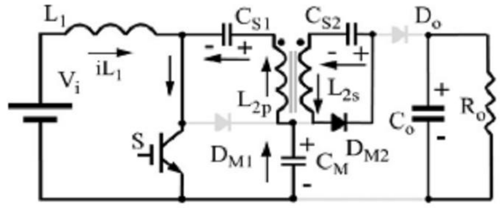

Fig. 5. First operation stage.

2)Second Stage ([t1, t2] Fig. 6) – From the instant t1 when the diode DM2 is blocked to the instant t2 when the power switch is turned off, the inductors L1 and L2 store energy and the inductor currents increase linearly.

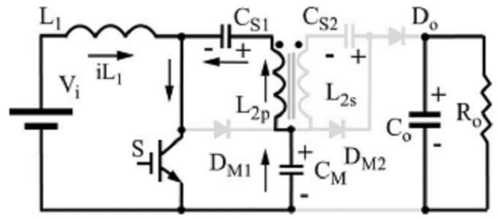

Fig. 6. Second operation stage.

3) Third Stage ([t2, t3] Fig. 7) - At the instant t2 the power switch S is turned off. The energy stored in the L1 inductor is transferred to the CM capacitor. Also there is the energy transference to the output thought the capacitors CS1, CS2 inductor L2 and output diode Do.

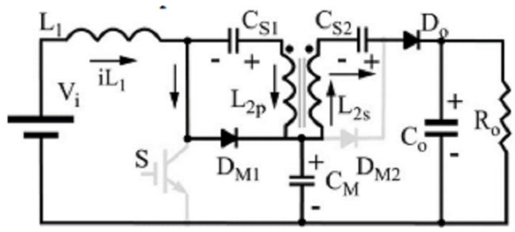

Fig. 7. Third operation stage.

4) Fourth Stage ([t3, t4] Fig. 8) - At the instant t3, the energy transference to the capacitor CM is finished and the diode DM1 is blocked. The energy transference to the output is maintained until the instant t4, when the power switch is turned on.

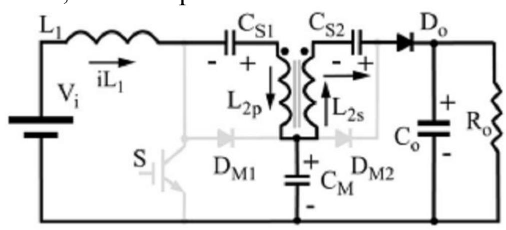

Fig. 8. Fourth operation stage.

5) Fifth Stage ([t4, t5] Fig. 9) – When the power switch is turned on at the instant t4, the current at the output diode Do decreases linearly and the d_i/d_t is limited by the transformer leakage inductance, reducing the diode reverse recovery current problems. When the output diode is blocked, the converter returns to the first operation stage.

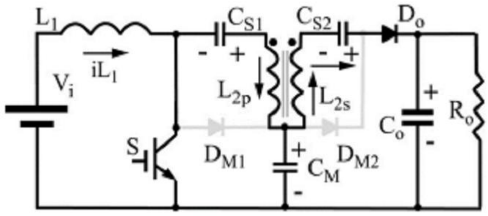

Fig. 9. Fifth operation stage.

The switch voltage and the voltage across all diodes are lower than the output voltage. The power switch turn on occurs with almost zero current reducing significantly the switching loss. The current variation ratio (d_i/d_t) presented by all diodes is limited due to the presence of the transformer leakage inductance, reducing the negative effects of the diode reverse recovery current.

The static gain of the modified SEPIC converter with magnetic coupling and voltage multiplier is equal to:

$$\frac{V_O}{V_i} = \frac{1}{1-D} \cdot (1+n)$$ -------------------- (1)

Where the transformer turns ratio (*n*) is calculated by:

$$n = \frac{N_{L2s}}{N_{L2p}}$$ -------------------- (2)

The static gain can be increased by the transformer turns ratio (*n*) without to increase the switch voltage. The switch voltage is calculated by (3)

$$\frac{V_{CM}}{V_i} = \frac{1}{1-D}$$ --------------------- (3)

V. CONCLUSION

From the project stage 1 we conclude that, the modified SEPIC converter with magnetic coupling, gives a very high static gain solution with minimizing the commutation losses, voltage stress and reverse recovery problem. And also gives a high efficiency as compared to modified SEPIC converter without magnetic coupling.

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