Single Phase PV Microinverter based on Interleaved Flyback Inverter

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Abstract—In this paper, topology of a Grid connected solar microinverter is proposed. The DC power obtained from the solar panel is converted into a rectified AC signal. This conversion is realized by an Active Clamped Flyback Converter. A full-bridge inverter which switched at a high frequency converts this rectified AC into sinusoidal AC of power frequency and this also controls the power flow direction to the grid. The topology is designed and simulated in PSIM software. The designed output values are verified with the simulated result.
Keywords- *Microinverter, Active Clamped Flyback Converter, full bridge inverter, EMI filter, decoupling capacitors.*

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I. INTRODUCTION

Renewable Energy resources like Wind generation systems and Solar photovoltaic (PV) systems have gained great importance during the past few years as promising and convenient renewable energy sources due to their promise of clear and seemingly limitless energy generated.

The rapid increase for the demand of solar PV systems is also due to increase in the manufacture and production of the crystalline panels that reduces overall costs and increases the efficiency of the PV panels. The power generated from solar panel is capable of supplying the local load as well as the grid at synchronous conditions. The PV systems supply solar electricity through an inverter directly to the load and to the electricity grid if the system is providing more energy than the load needs. Interfacing a solar inverter module with the power grid involves two important events. First is to ensure that the solar inverter module is operated at the Maximum Power Point (MPP). The second is to inject a sinusoidal current into the grid. The main specification of the standalone solar inverter is that current must be drawn from the PV panel and delivered to the utility load at unity power factor.

The solar inverter systems are classified into the following three types:

- Centralized inverters
- Sting inverters
- Microinverters

Centralized Inverters contain high power solar panel and a high power converter inverter module. This eventually results in losses as well as high costs.

Solar String Inverter is a type of inverter which is designed to operate with several serial or parallel connected PV modules. The string inverter converts the direct current output from each panel in to alternating current. The design of string inverter involves parallel connection of few multiple, independent panel units in a modular way.

Micro inverter contains single low power converter inverter module for each single solar panel. It is less prone to the problems of shading and PV cell malfunctioning. It has become an emerging product and has promised a remarkable market share in future. Hence this topology has been selected for the present work which is shown in the figure 1.

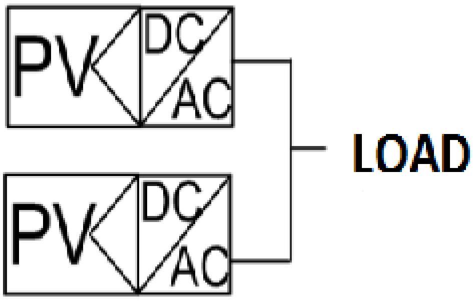

Figure 1. Microinverter

In this work, a novel topology of Active Clamped Flyback Converter and Full bridge Inverter module is proposed. The Active Clamped Flyback Converter is operated in Boost mode and the output voltage of this DC-DC converter has the wave shape of a rectified AC signal. This is then directly converted into AC of required power frequency. This reduces the efforts vested for wave shaping.

The section 2 below presents the block diagram and working principle of the Solar Microinverter. Section 3 deals with the design of the proposed module. In the Section 4, we present the simulation results and in the conclusion and analysis in Section 5.

II.CIRCUIT DIAGRAM AND WORKING PRINCIPLE

Figure 2 below represents the block diagram of the single phase standalone Microinverter module.

The input is obtained from the series and parallel connection of PV cells. Decoupling capacitors are connected in parallel with the input supply to eliminate the input ripple and noise signals. They also serve as energy storage elements between input and output. The decoupling capacitor voltage is boosted using Active Clamped Flyback Converter and then

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inverted using Full Bridge Inverter. Electromagnetic Interference Filter is connected at the output of the inverter for the protection of module against the transient spikes. The input voltage derived from an array of PV panels is about 20-45V, and rated for 215W.

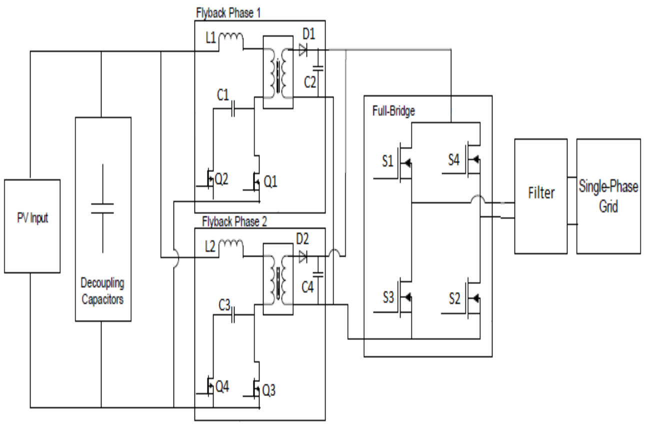

Figure 2. Interleaved flyback microinverter topology

III DESIGN OF THE MODULE

The design of the decoupling capacitors and the DC-DC Converter is discussed below.

A. Decoupling Capacitors

An energy storage element called decoupling capacitors are used at the input of the solar string inverter. The purpose of these capacitors are to balance the different instantaneous powers in the system. To maximize the energy which is harvested from PV panel, the input power from the PV panel has to remain constant and the power mismatch will be there between the input power and output power. The bulk decoupling capacitors are also required to reduce the ripple voltage from the PV panel in order to achieve a utilization factor greater than 99% (maximum power utilization) given by $P_{MPP.}$ The value of the decoupling capacitance is calculated from (1)

$$C_{bulk} = \frac{P_{MPP}}{2\pi \cdot f_{ripple} \cdot V_{mpp} \cdot V_{ripple}} \quad (1)$$

The ripple voltage is determined from (2) below

$$V_{ripple} = \sqrt{\frac{(k_{pv} - 1) \cdot 2 \cdot P_{MPP}}{3 \cdot \alpha \cdot V_{MPP} + \beta}} \quad (2)$$

Where α and β are co-efficients of the polynomial equation and K_{pv} is the utilization factor. The above equations are calculated from [3].

B. Active Clamped Flyback Converter

The Fig. 2 below shows the Active Clamped Flyback Converter topology.

The Flyback converter has been selected as a single stage topology because it can step up the PV panel voltages to a rectified AC output, and also provide galvanic isolation between the PV panel and the grid. The Forward converter can also be used to boost the PV panel voltage and provide galvanic isolation. But the flyback converter requires fewer components than forward converter since there is no need of output inductor and freewheeling diode at the output side. Hence the flyback topology has been adopted.

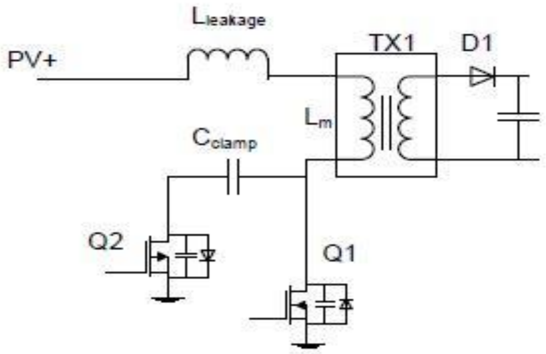

Figure 3. Active clamped flyback converter topology

One of the biggest issue of flyback topology is handling the leakage energy. During the operation of the circuit, when the flyback MOSFET turns off, large amount of energy produced in the core is not transferred to the flyback secondary side. Due to this energy large voltage spikes are caused, which may be destructive for the MOSFET. The snubber circuit consisting of traditional Resistor, Capacitor and Diode (RCD) can be added across the flyback transformer primary to dissipate the energy through heat as given in [4]. This RCD snubber will protect the flyback MOSFET but it has negative impact on the system efficiency.

The proposed solar string inverter module incorporates an active clamp circuit that is a lossless snubber. The clamping capacitor (C_{clamp}), is used for clamping the leakage spike and the left over energy is stored in clamping capacitor. Then this left over energy is transferred to the flyback transformer secondary and thus recycling the energy. If this topology is implemented correctly, it also provides Zero voltage switching (ZVS) on the MOSFET used in flyback by which the switching losses are reduced and overall efficiency increases.

An auxilliary switch i.e. P-channel MOSFET is chosen to eliminate the need of a high side gate drive circuit. If the clamp MOSFET was across the transformer winding instead between the winding and the ground then there is a need of high gate drive circuit. Hence this topology is called P-type clamp circuit explained in [5]. To drive the P-Channel MOSFET, a negative voltage between the gate and source is required.

The Inductor ripple current of DC-DC converter is shown by (4).

$$I_L = \frac{V_{PV} \cdot \left(\frac{d}{f_{sw}}\right)}{L_M} \quad (4)$$

The resonant frequency of the clamping network is given by

(5).

$$f_r = \frac{1}{2\pi \cdot \sqrt{L_{leakage} \cdot C_{clamp}}} \quad (5)$$

The Flyback transformer is designed to meet the specified values of input voltage, output voltage and output power. The values of leakage inductance, magnetizing inductance and switching frequency are calculated from the necessary equations.

C. Single Phase Bridge Inverter

A full-bridge type circuit is connected to the output of the flyback converter. The Figure 4 represents the single phase bridge inverter model. The full-bridge circuit is an unfolding circuit for the rectified output voltage of the flyback that controls the output power direction. The output to be obtained is Alternating voltage of 230V and 50Hz. The full-bridge MOSFETs are driven at 2x the line frequency (100 kHz). This reduces the switching losses of the switches during on and off.

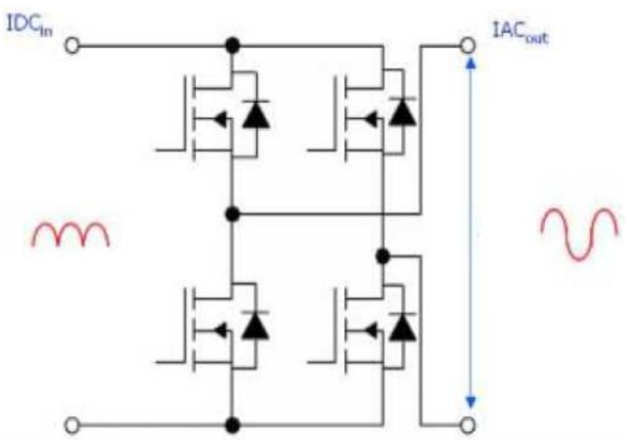

Figure 4. Single phase bridge inverter topology

D. EMI Filter

An Electromagnetic Interference (EMI) filter is connected to the output of the full-bridge unfolding circuit. The EMI filter consists of a common-mode choke and a differential An Electromagnetic Interference (EMI) filter is connected to the output of the full-bridge unfolding circuit in hardware designs. This filter has been designed with off-the-shelf components that are rated appropriately. Usually at the output of the EMI filter is a 430V varistor across the Line/Neutral terminals, which will add additional protection against transient voltage spikes. After the varistor are two fuses, one in the AC line path and one in the neutral path.

IV. SIMULATION CIRCUIT AND RESULTS

The Active Clamped Flyback DC-DC Converter has been designed and simulated on PSIM software. Table I below shows the designed parameter values. Figure 6 shows the gating pulse for main switch and clamp switch. Figure 7 shows the output voltage waveform of the Active clamp DC-DC converter and output voltage waveform of the proposed solar microinverter circuit.

TABLE I. SIMULATION PARAMETERS

Simulated parameter	Designed value
Input Voltage Range	25 - 45 V
Maximum input power	250W
Decoupling Capacitor	11 µ F / 100V
Flyback Inductance	0.22 H
Duty Cycle	50%
Maximum Output Power	215W
Output Voltage	230V AC

The simulation circuit is as shown in the figure 5.

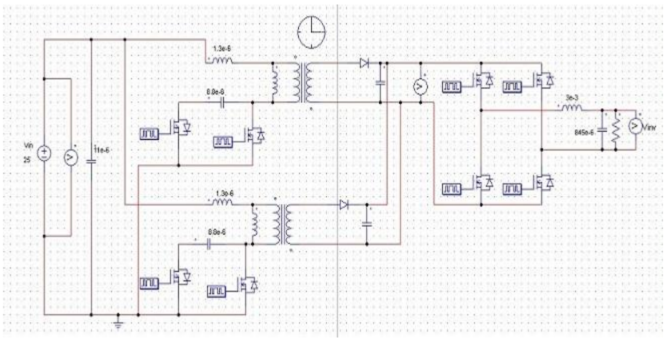

Figure 5. Simulation of the proposed circuit

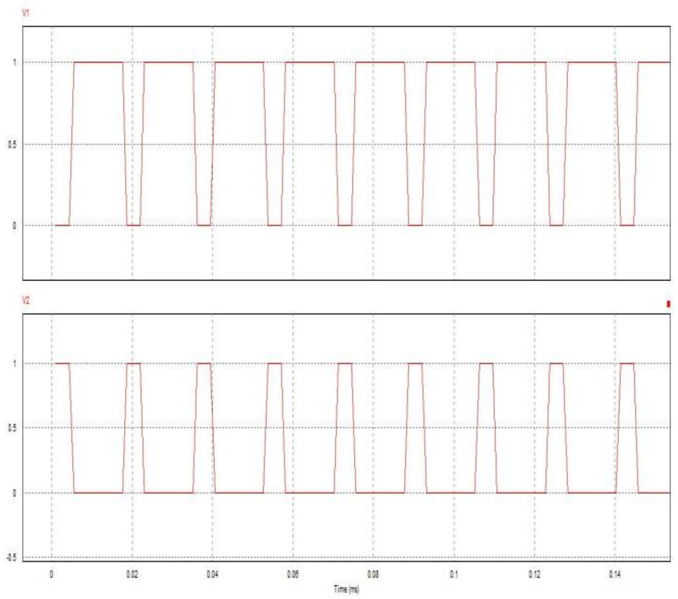

Figure 6. Gating pulses for the MOSFET switches

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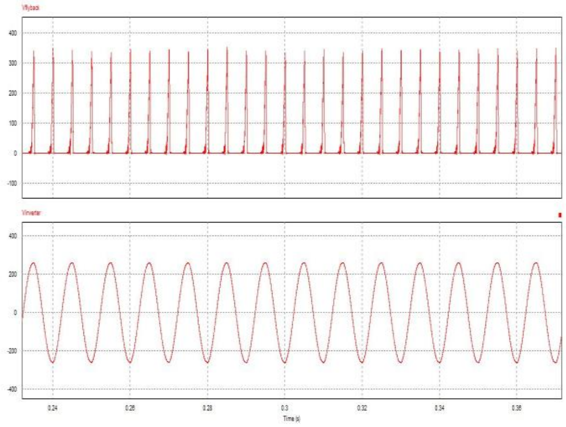

Figure 7. Output voltage of active clamp DC-DC converter and inverter output

V CONCLUSION

A work has been carried out on grid connected solar microinverter design. The topology has been implemented for a single stage active clamp interleaved flyback DC-DC converter. The power output obtained is found to be around 215W.The design has been verified on PSIM software and the simulated output obtained are in good agreement with the designed values.

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