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New LCDD Snubber Dedicated for Grid Converter Flyback Micro Inverter

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***Abstract*—The current source flyback microinverter is a popular topology for implementing low power. However, the high voltage spikes caused by the leakage inductance of the microinverter transformer can damage the main switch when it is turned OFF. Therefore, a turn-off snubber is needed to limit the rate of rise voltage across the switching device. A low-cost technique for improving the efficiency of this single-stage flyback microinverter is proposed in this paper. The proposed efficiency improving technique is based on a simple snubber, consisting of just a few passive elements.**

In order to meet this goal, the design of the converter with the passive snubber is presented, and evaluated. The regenerative snubber is based on LCDD snubber.

In the paper, the flyback microinverter with the passive regenerative snubber is presented, the converter operation modes are discussed and analyzed and the design of the converter with the passive snubber is reviewed.

***Index Terms*—Flyback micro inverter, regeneration, snubber, LCDD, DCM, BCM, CCM, MPPT**

NOMENCLATURE

N	: turn ratios (N=Np/Ns)
Lm	: magnetizing inductance
I1pk	: maximum transformer primary current
Dmax	: maximum duty cycle
fs	: switching frequency of primary switch S1
Vpv	: input voltage from photovoltaic panel
Vgrid	: RMS grid voltage
Vgridmax	: Maximum grid voltage
DCM	: Discontinuous conduction mode
BCM	: Boundary conduction mode (between continuous and discontinuous) conduction mode.
CCM	: Continuous conduction mode

I. INTRODUCTION

Renewable energy sources are becoming more popular due to environmental concerns and the need for more energy. Solar energy systems based on photovoltaic cells are an example of alternative renewable energy system.

DC-AC flyback micro inverter based on the flyback topology, this converter makes use of only one magnetic component to attain both the energy transfer and isolation [1]-[2].

The challenge in the design of the DC-AC flyback micro inverter is handling the leakage inductance energy of the flyback transformer. However, when the main transistor is turned OFF the high leakage inductance of the transformer develops high voltage spikes across the main switch and can cause his destruction. Conventional RCD Snubber is a popular and simple circuit to limit the peak voltage stress [3] [8]. However, the use of the RCD snubber dissipates all of the energy absorbed, as a result of this, the RCD snubber power loss is not insignificant. Consequently, the conventional RCD Snubber cannot meet the requirements of the high efficiency objective.

In order to improve the converter efficiency, various methods have been proposed, including the use of the zero-voltage switching techniques (ZVS) with active snubbers [8]-[9], and zero-current switching techniques (ZCS) with active snubbers [10]-[11], and the use of the no dissipative LC snubbers [5]-[7]. The no dissipative *passive LCDD* snubber can improve the converter efficiency; nevertheless, as compared to the passive RCD dissipative snubber, *LCDD* snubber requires an additional inductor that increases the component count and cost.

The recently introduced energy regenerative snubber can recover the energy captured by the snubber capacitor to the dc bus and, improve the efficiency of the flyback inverter [10]. In this paper, design of energy regenerative snubber is performed.

II. Converter design

In this section the main converter of Flyback micro inverter is discussed. The converter can operate in three modes DCM, BCM and CCM

the design of flyback micro inverter is based on same consideration:

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-the micro inverter operates in DCM mode so that a sinusoidal output can be achieved
The AC grid voltage Vg(t) can be expressed as:

$$\boldsymbol{Vg(t) = Vgmax.sin\,(wg.t)} \quad (1)$$

-the most important components that needs to be considered for the DCM mode is the magnetizing inductance Lm of the transformer and the turn ratio N . A low value of Lm increases the pick magnetizing current in the transformer. for this consideration the stress in the switch Sp increases. In the other hand, a high value of Lm, affect the current and move toward continuous conduction mode (CCM)
. In this study, DCM mode was discussed. The flyback micro inverter is shown in fig1.
The converter operates in this sequence:
-When the primary switch Sp is turned on, energy from the PV panel and primary capacitor is transferred and stored in the magnetizing inductance of the main transformer. Consequently, the current in the primary winding of the transformer augments linearly
-When the primary switch Sp is turned off, stored energy in the transformer is transferred to the AC grid through D1 and Ss1 when the grid voltage is positive and D2 and Ss2 is negative.
Operating in DCM mode energy in the transformer was discharged during only switching cycle in order to inject a sinusoidal current in the grid, the duty cycle of Sp must be made to vary throughout the AC voltage. For this reason, converter PLL control is used to track and synchronise with the AC grid voltage
The magnetizing inductance of transformer can be expressed:

$$L_m = \frac{1}{4}(Vpv)^2 \frac{Dmax^2}{fs\ Pout} \quad (2)$$

The turn ratio of transformer is:

$$N \geq \frac{Vpv}{Vgmax}\left(\frac{1}{Dmax} - 1\right)^{-1} \quad (3)$$

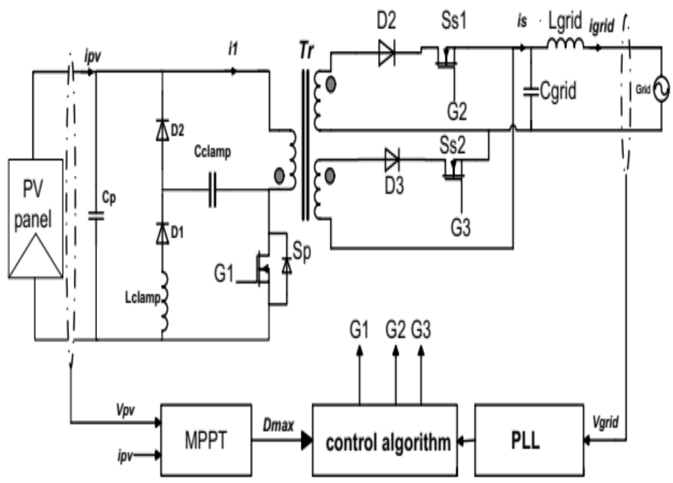

Fig.1. Flyback micro inverter and LCDD snubber

I. Snubber design

When the primary switching balance between the on state and the off state, energy stored in the leakage inductance of the transformer damages the main switch. For this reason, many techniques are used to protect switch. RCD snubber is used to limit the spike voltage in the primary switch but energy is dissipated in the resistor and reduced efficiency of micro inverter.
LCDD snubber presents a passive regenerative snubber who can reduce the spike voltage in the main switch and regenerate leakage energy from transformer to primary capacitor. For this reason, LCDD snubber increases efficiency of micro inverter and reduces the stress of main switch.

I. RCD snubber

RCD clamp circuit is used to limit the peak voltage in the primary switch Sp when he balanced to off state. RCD snubber is used to balance the leakage energy to clamp capacitor Cclamp in the first state and dissipate balanced energy in the RCD resistor.
The power associated with leakage primary inductance Lk is expressed by:

$$P_{lk} = \frac{1}{2} L_K I_{1PK}^2 f_s \quad (4)$$

The power dissipated by the RCD clamp by:

$$P_{sn}^{max} = P_{lk}\left(1 + \frac{N.V_g}{V_x^{max}}\right) \quad (5)$$

Where NVg is the reflected voltage from secondary to primary during off state of primary switch and V_x^{max} the limited spike voltage in the primary switch Sp.
The RCD clamp resistor should be selected using equation:

$$R = \frac{2 * V_x T_s (NV_g + V_x^{max})}{L_K I_{PK}^2} \quad (6)$$

The power dissipation in the resistor is:

$$P_{sn} = \frac{(V_x + NV_g)^2}{R} \quad (7)$$

II. LCDD snubber

LCDD snubber consists of the uses of inductance Lclamp, capacitor Cclamp and two diodes (D1,D2). When the primary switch Sp is turned off, energy in the leakage inductance of the main transformer is transferred in the clamp capacitor Cclamp. In the next switching cycle of Sp, energy stored in Cclamp is transferred to the inductance Lclamp through Sp and transferred and reinjected in the primary side of converter.
Clamp capacitor is determined by considering energy balance between clamp capacitor Cclamp and leakage inductance in the

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transformer Lk when the switch Sp is turned off. Energy balance can be expressed as:

$$\frac{1}{2} C_{clamp} \Delta V_{clamp}^2 = \frac{1}{2} L_K I_{1PK}^2 \quad (8)$$

Where ΔV_{clamp} is the maximum voltage across the snubber capacitor Cclamp. An allowable clamp capacitor voltage is predetermined. The clamp capacitor Cclamp is expressed by:

$$C_{clamp} = \frac{L_k I_{1PK}^2}{\Delta V_{clamp}{}^2} \quad (9)$$

III. *Experimental results*

The proposed converter was simulated using PSIM software. The converter was implemented with the following specifications:

Table 1. Simulation Inverter Parameters

Parameters	value
Rated output power Ps	250W
Switching frequency fs	20Khz
Magnetizing inductance Lm	17µH
PV input voltage Vpv	40V
Grid frequency fgrid	50Hz
Input capacitor Cp	10mf
Turn ratio of transformer N	0.11
Output filter capacitor	800nf
Output filter inductance	2mH
Cclamp	3uf
Lclamp	20uH
Duty cycle	0.44

The primary transformer current i1 is presented by fig 6, the current reached 48A.Micro inverter operates as a current source Grid voltage and current are presented by fig.2 and fig.3. Using LCDD snubber reduce the stress in the primary switch Sp when he is switched to off state (Fig.4 and Fig.5) and is limited to 110V.

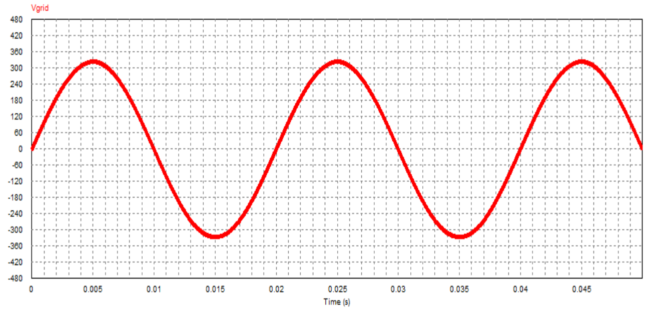

Fig.2.grid voltage

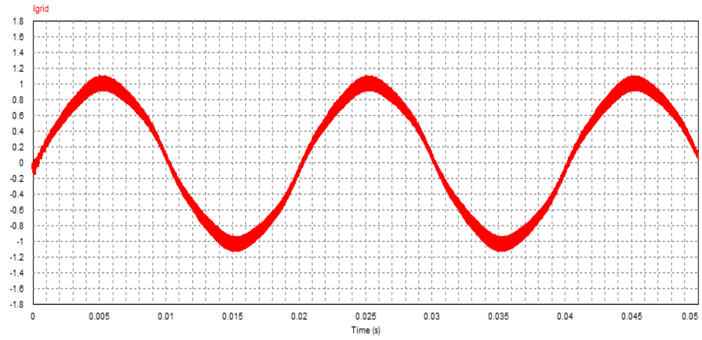

Fig.3.injected grid current i_{grid}

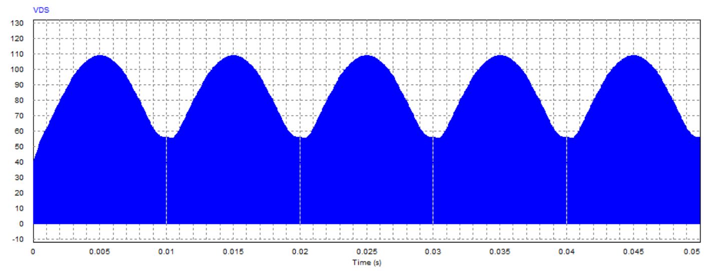

Fig.4.Drain Source primary switch voltage

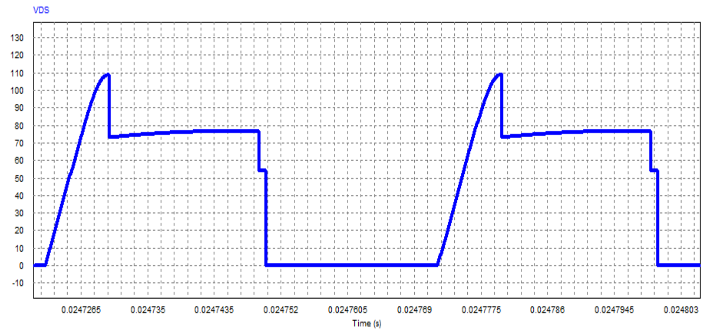

Fig.5.Stress Drain Source voltage Sp switch

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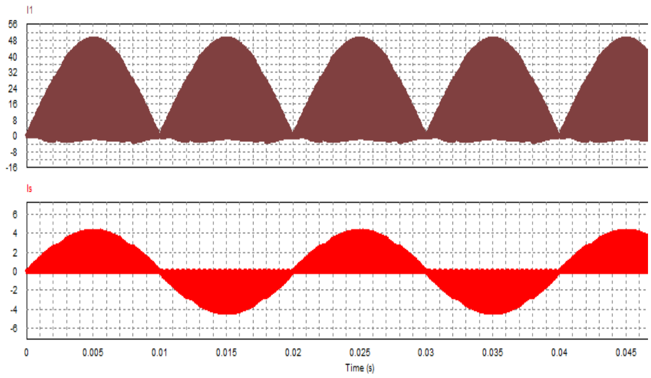

Fig.6. Primary current i1 and Secondary current i_s

IV. *Conclusion*

LCDD snubber presents a solution to increase efficiency of flyback micro inverter compared to RCD snubber. Using an external winding Lclamp presents a low-cost solution but increase the converter size. Another solution consists to integrate axillary winding Lclamp in the main transformer.

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