International Journal of Scientific Research & Engineering Technology (IJSET)
Vol.13 pp.38-42

Design and control of current source flyback micro inverter for single grid connected photovoltaic systems

Elyes Mbarek[#1], Hamed Balloumi[*2], Ferid Kourda[#3]

[#]*Université de Tunis El Manar, ENIT-L.S.E, BP 37, 1002 Tunis Ie Belvédère, Tunis, Tunisia*

[1]Mbarek.Elyes@gmail.com

[2]hamed.balloumi@enit.rnu.tn

[3]*Ferid.kourda@enit.utm.tn*

***Abstract*—The proposed design of current source micro inverter system is used to connect PV panel to the grid with achieving maximum Power Point Tracking (MPPT) control. The main advantages of the proposed micro inverter are: low cost, high efficiency, high power density and high power factory regulation.**
The proposed Flyback micro inverter operates in discontinuous conduction mode (DCM) where a constant switching frequency control is applied.
The design and the control are validated by personal computer simulation program (PSIM) and experimental laboratory prototype is accomplished

***Keywords*— Single-Stage, Grid-Connected, Micro inverter, Flyback, DCM, MPPT, current source**

I. Introduction

Solar energy presents a promising source for producing clean electricity generation.

In the world, there are two potential markets for electric power generation from photovoltaic (PV) systems:

- Large-scale (up to several megawatts) power plants sized used in desert regions with high insolation, PV standalone or grid-connected systems for professional use
- Small-scale residential applications, where the PV power production usually varies between 0.1 and 5 kW.

The use of several decentralized grid connected PV systems is quite more appropriate as they can also be easily installed on buildings.

Technology on decentralized grid-connected PV systems is so-called "ac–PV module". Ac–PV module is the combination of a single PV module and a single phase power electronic inverter. Power process unit of Ac-PV module is usually a single phase controllable power converter, power range from 50–400 W.

Ac-PV inverter is mounted either on the rear side of the module or on the support structure and is directly connected to the PV module. The concept of ac–PV module supports optimal adjustment between the PV module and the inverter, which may lead to an overall better performance

II. Proposed micro inverter

Fig.1 presents the proposed Flyback micro inverter performs energy from DC side to the AC grid site. Micro inverter includes different parts:

- High frequency transformer with three windings: one primary and two secondary
- A primary controlled switch S1 is modulated in high frequency, duty cycle should be made to vary throughout the AC voltage line cycle.
- The two secondary controlled switches placed in each secondary winding SV2 and SV3 are modulated with grid frequency. Each of them is able to transfer energy to the AC side during a utility grid half cycle and they ensure an AC output wave form synchronized with the grid.
- LC filter is used to filter the current produced by the rest of the converter; so that the appropriate final output current is produced and fed to the grid.

The control bloc of Flyback micro inverter includes:

- Phase locked loop PLL bloc that generates signal, controls each controlled switch SV1,SV2 and SV3
- A maximum power point extractor MPPT bloc that calculates the duty cycle Dmax in order to extract the maximum power from photovoltaique panel

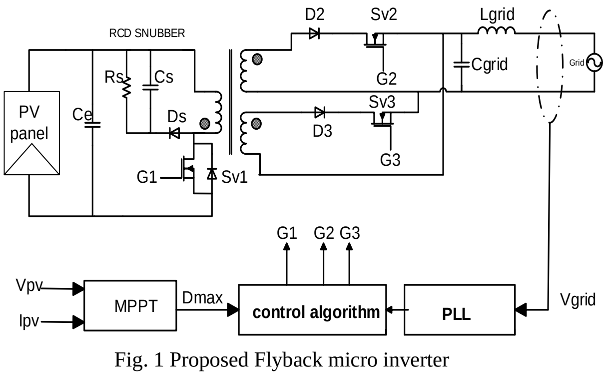

Fig. 1 Proposed Flyback micro inverter

ISSN 1737-9296

The switching sequence of each semiconductor can be observed in Fig.2.

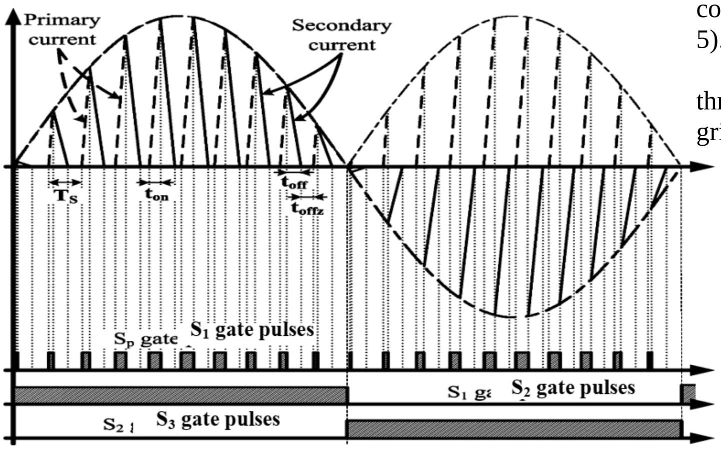

Fig.2 switching sequence of SV1, SV2 and SV3

III. OPERATION MODE OF FLYBACK MICRO INVERTER IN DCM MODE

When the primary switch SV1 is on; the primary current I1 in the primary winding of transformer increases, the energy coming from the solar PV panel is stored in the magnetizing inductance Lm of the HF transformer.

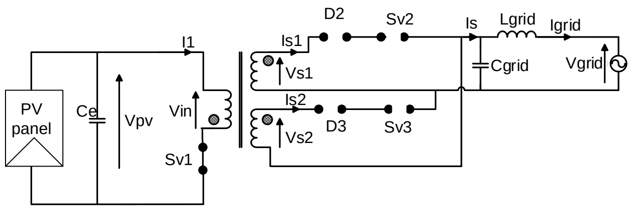

Fig4. Micro inverter when primary switch Sv1 is on

The voltage at the primary winding of transformer is:

$$Vin = NVg(t) = Lm\frac{dI1(t)}{dt} \quad (1)$$

When N is the turns ratio (N=Np/Ns), Lm magnetizing inductance.

The pic value of primary current I1max can be expressed

$$I1max = \frac{Vin.dmax}{Lm.fs} \quad (2)$$

The ton_max can be expressed as:

$$ton_{max} = dmax.Ts = \frac{dmax}{fs} \quad (3)$$

When dmax is the maximum duty cycle and fs the switching frequency of primary switch SV1, The AC grid voltage can be expressed as:

$$Vg(t) = Vgmax.sin(wg.t) \quad (4)$$

When SV1 is off, the stored energy in the HF transformer will transfer to the grid through the output rectifier D2 and the controlled switch SV2 if the grid voltage Vgrid is positive (Fig 5).

The stored energy in the HF will transfer to the grid, through the output rectifier D3 and control switch SV3 when grid voltage Vgrid is negative (Fig 6).

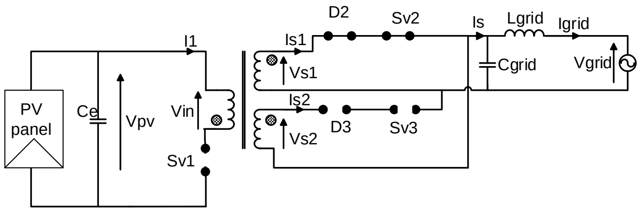

Fig5. Micro inverter when primary switch Sv1 is off

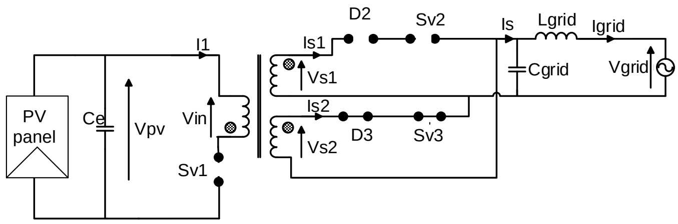

Fig.6 Micro inverter when primary switch Sv1 is off

The proposed flyback micro inverter operates in discontinuous conduction mode (DCM) due to its simplicity of control

To operate in DCM, the maximum duty cycle can be expressed:

$$dmax \leq \frac{1}{\frac{Vin}{NVgmax}+1} \quad (5)$$

The magnetique inductance Lm can be expressed

$$Lm = \frac{1}{2}\left(\frac{Vin}{Vgmax}\right)^2 \frac{dmax^2\,Vgmax^2}{fs * Lm} \quad (6)$$

IV. SIMULATION RESULTS

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

Table 1
Inverter parameters

Parameters	value
Rated output power Ps	150W
Switching frequency fs	60Khz
Magnetizing inductance Lm	6.65µH
PV input voltage Vpv	30V
Grid frequency fgrid	50Hz
Input capacitor Ce	10µf

ISSN 1737-9296

Turn ratio of transformer N	0.11
Output filter capacitor	300nf
Output filter inductance	2mH

Fig.7 shows the voltage value across SV1 switch. The voltage is zero for the conduction phase of the transistor. The overvoltage reaches 120V caused by leakage inductance of the transformer

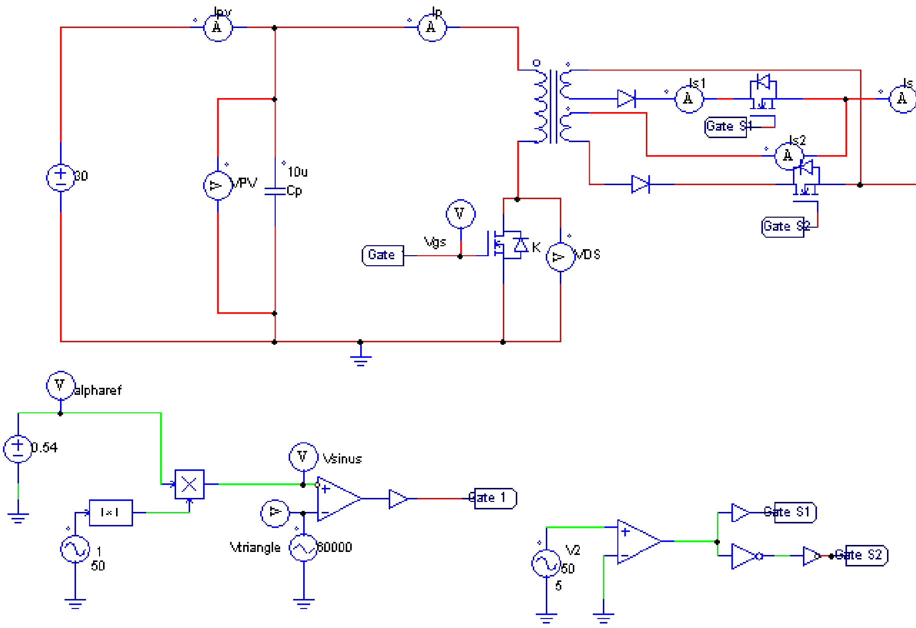

Fig.7 inverter simulating using PSIM software

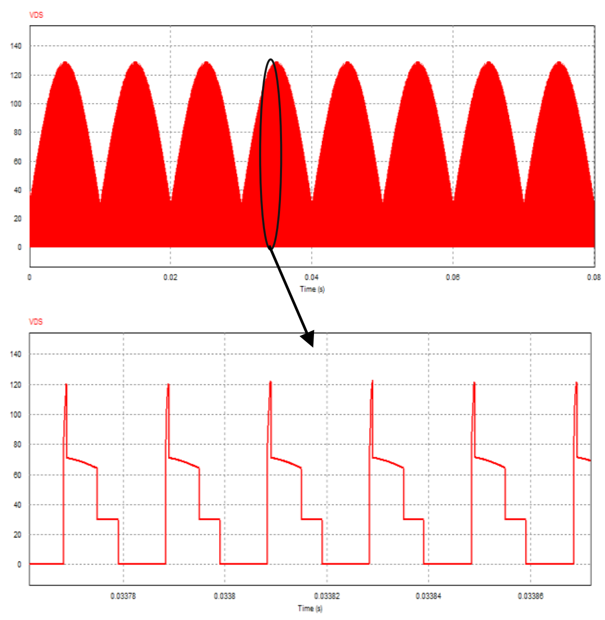

Fig.8 voltage value across SV1 switch

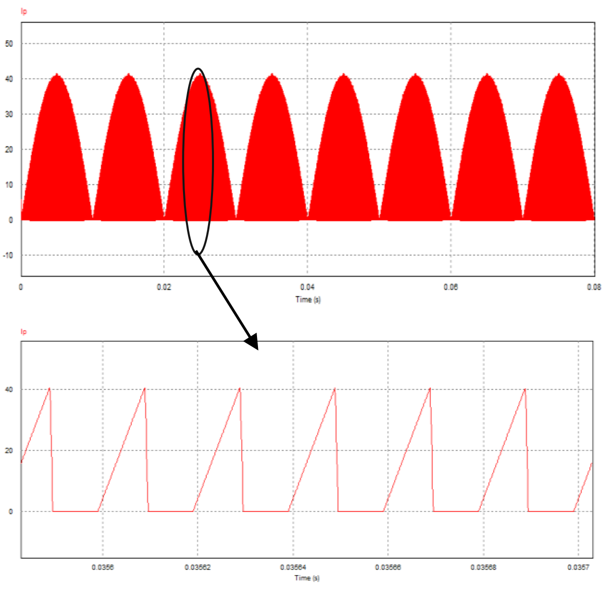

Fig.9 primary transformer current Ip

Fig.9 shows the primary transformer current Ip. The current reaches 40A, when the primary switch SV1 is on

Fig.9 shows the secondary currents IS1 and IS2 before filtering for the case of 150W constant active power transfer. Fig.10 and Fig.11 show grid injected current and grid voltage after CL filter.

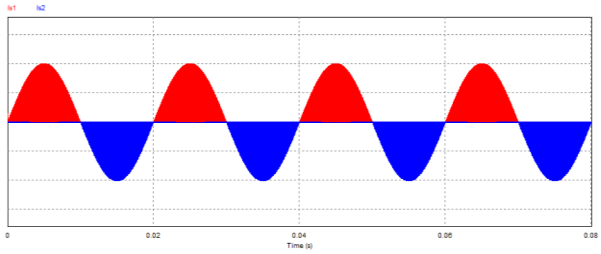

Fig.9 secondary current IS1 and IS2

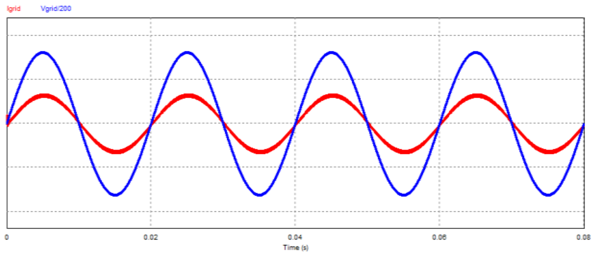

Fig.10 output voltage and current

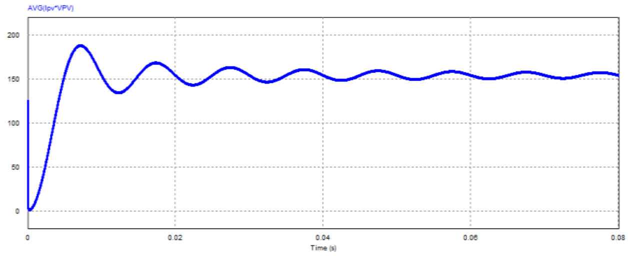

Fig.11 injected power

V. Experimental Results

Laboratory experimental prototype was built (Fig. 12), with the component values selected by the algorithm. The flyback inverter is controlled by the STM32F407 microcontroller.

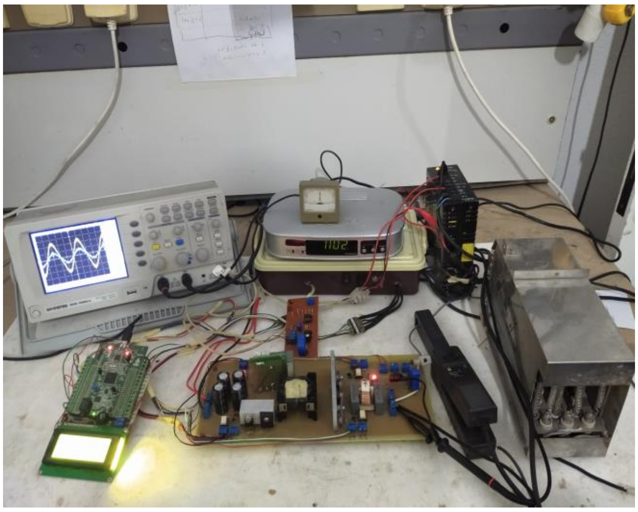

Fig.12 experimental prototype

Fig. 13 shows the inverter output current and voltage injected in the load with unit power factor.

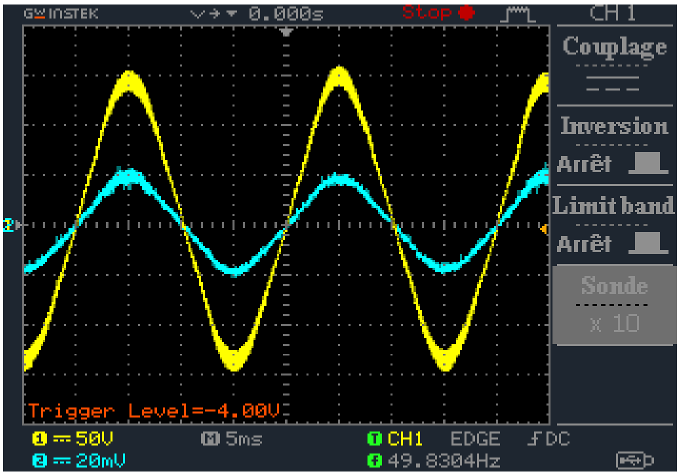

Fig.13 load voltage (ch1,50V/div) and current (ch2,200mA/div)

VI. Conclusion

The advantages of the flyback current source inverter qualify it to be used as a single stage converter in photovoltaic modules. The proposed micro inverter operates in discontinuous conduction mode (DCM) where a constant switching frequency control is applied. Flyback micro inverter can also operate in BCM and CCM but control mode is complicate and must operate in a closed loop control.

A. *References*

[1] D. Meneses, F. Blaabjerg, O. Garcia and J. Cobos, "Review and comparison of step-up transformer less topologies for photovoltaic ac-module application," IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2649 -2662, Jun. 2013.

[2] T. Freddy, N. A. Rahim, W. P. Hew and H. S. Che, "Comparison and Analysis of Single-Phase Transformerless Grid-Connected PV Inverters," IEEE Trans. Power Electron., vol. 29, no. 10, pp. 5358 - 5369, Oct. 2014.

[3] A. Ch. Kyritsis, E. C. Tatakis and N. P. Papanikolaou, "Optimum design of the current-source Flyback inverter for decentralized grid-connected photovoltaic systems," IEEE Trans. Energy Conv., vol.23, no.1, pp. 281-293, Mar. 2008.

[4] Z. Zhang, X.-F. He and Y.-F. Liu, "An optimal control method for photovoltaic grid-tied-interleaved Flyback micro inverters to achieve high efficiency in wide load range," IEEE Trans. Power Electron., vol. 28, no. 11, pp. 5074–5087, Nov. 2013.

[5] A. C. Nanakos, E. C. Tatakis and N. P. Papanikolaou, "A weighted-efficiency-oriented design methodology of flyback inverter for ac photovoltaic modules," IEEE Trans. Power Electron., vol. 27, no. 7, pp. 3221- 3233, Jul. 2012.

[6] H. Hu, S. Harb, N. H. Kutkut, Z. J. Shen and I. Batarseh, "A single-stage micro inverter without using eletrolytic capacitors," IEEE Trans. Power Electron., vol. 28, no. 6, pp. 2677–2687, Jun. 2013.

[7] Y. Li and R. Oruganti, "A Low Cost Flyback CCM Inverter for AC Module Application," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1295–1303, Mar. 2012.

[8] T. V. Thang, N. M. Thao, J.-H. Jang and J.-H. Park, "Analysis and design of grid-connected photovoltaic systems with multiple-integrated converters and a pseudo-dc-link inverter," IEEE Trans. Ind. Electron., vol.61, no. 7, pp. 3377–3386, Jul. 2014.

[9] F. F. Edwin, W. Xiao and V. Khadikar, "Dynamic modeling and control of interleaved flyback module integrated converter for PV power applications," IEEE Trans. Ind. Electron., vol. 61, no. 3, pp. 1377–1388,Mar. 2014.

ISSN 1737-9296

[10] G. C. Christidis, A. C. Nanakos and E. C. Tatakis, “Hybrid Discontinuous/Boundary Conduction Mode of Flyback Microinverter for AC-PV Modules,” IEEE Trans. Power Electron., vol. 31, no. 6, Jun. 2016.

[11] G. S. Dimitrakakis, E. C. Tatakis and E. J. Rikos, “A semiempirical model to determine HF copper losses in magnetic components with nonlayered coils,” IEEE Trans. Power Electron., vol. 23, no. 6, pp. 2719-2728, Nov. 2008.

[12] K. Venkatachalam, C. R. Sullivan, T. Abdallah and H. Tacca, “Accurate prediction of ferrite core loss with non-sinusoidal waveforms using only Steinmetz parameters,” Proc. IEEE Comput. Power Electron. Conf., 2002, pp. 36-41.

ISSN 1737-9296