IMPLEMENTATION OF BIDIRECTIONAL FLYBACK CONVERTER IN LIGHTING INTEGRATED SYSTEM

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***ABSTRACT**: The objective of this paper is to design a multifunctional bidirectional converter applied to lighting system. On one hand, during sunlight hours, the converter will behave as an inverter, injecting in the grid the power generated by the PV panel. On the other hand, during the absence of sunlight, it will work as a rectifier in order to supply the LED lamp.The converter while working in rectifier mode produces output with high power factor and reduced harmonic distortion. The proposed topology is based on the integration of two Flyback converters, one for each half-cycle of the grid voltage, avoiding the usual diode bridge rectifier for LED lamps drives, thus providing a bidirectional power flow. Simulation and experimental results are presented to verify the operation of the converter. MATLAB SIMULINK is used as the software platform for development of the model and its analysis. A prototype of the proposed electronic stage has been designed, built and tested, in order to validate the system.*

I. INTRODUCTION

Photovoltaic energy has become one of the major research topics in the last few years, due to a significant increase of the total power installed worldwide. Environmental impact has become one of the main concerns about the energy generation; however, the extensive use of PV panels contributes to a reduction of this impact caused by non-renewable energy sources.

LED technology has become an attractive and widespread solution for SLS due to latest developments like increment of luminous flux, luminous efficacy and long useful life. This project proposes a multifunctional system, which integrates a SLS based on LEDs with a grid-tie PV power generation system, composing a single lamppost with the LED luminaire and PV panel. Therefore, there will be two operation modes: on one hand, during sunlight hours, the converter will behave as an inverter, injecting in the grid the power generated by the PV panel. On the other hand, during the absence of sunlight, it will work as a rectifier in order to supply the LED lamp. The proposed topology is based on the integration of two Flyback converters, one for each half-cycle of the grid voltage, avoiding the usual diode bridge rectifier for LED lamps drives, thus providing a bidirectional power flow. Figure 1 shows the block diagram of proposed system.

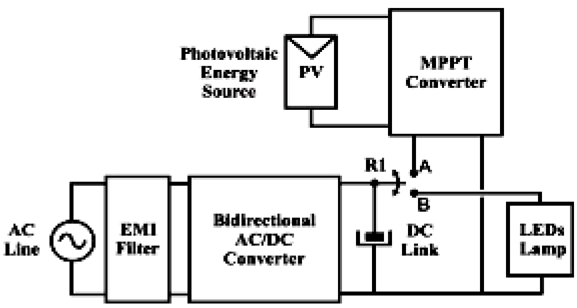

Fig.1 Block diagram

II. CIRCUIT CONFIGURATION AND PRINCIPLE OF OPERATION

A.FLYBACK CONVERTERS

Flyback converters are widely used in low power lighting applications, as well as in renewable energies systems. The main advantages of this converter are the galvanic insulation, simple structure, low cost and high efficiency. Figure 2 shows the proposed topology of the bidirectional Flyback converter. The proposed topology is composed by the integration of two Flyback converters that work symmetrically, one in each half-cycle of the grid voltage. Thus, this avoids the diode bridge rectifier, allowing a bidirectional energy flow for the proper system operation. The converter works in Discontinuous Conduction Mode (DCM) in both operation modes.

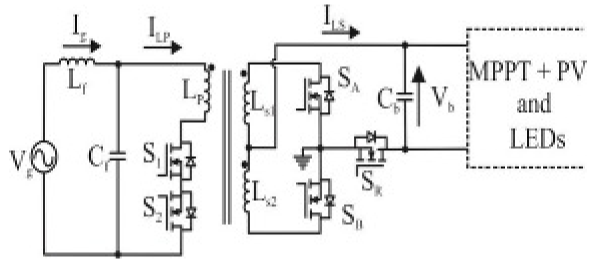

Fig.2 Circuit diagram of flyback converter

Switches driving signals, together with the main waveforms of the bidirectional converter are shown in figure 3. It is possible to observe that, for both operation modes, it is necessary a synchronism with the grid voltage, which is performed by a zero cross detector.

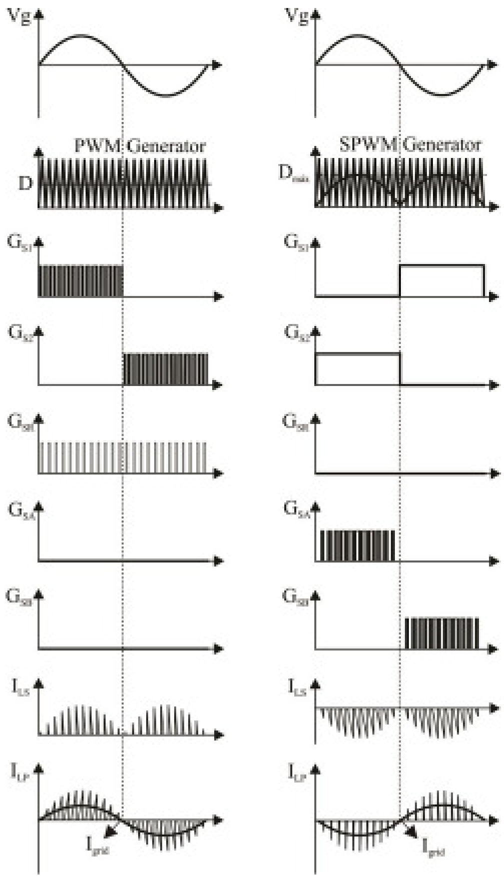

Fig.3 control signals and main waveforms for both modes

B.OPERATING MODES
This system operates in two different modes:

- Rectifier mode
- Inverter mode

RECTIFIER MODE:
During the rectifier mode, a Pulse Width Modulation (PWM) is used to generate the command signals for S1 and S2, with a constant modulating signal. This modulation results in a constant duty cycle, and since the Flyback converter is working in DCM, it behaves as a loss-free resistor. Switches S1 and S2 operate at high frequency in rectifier mode.

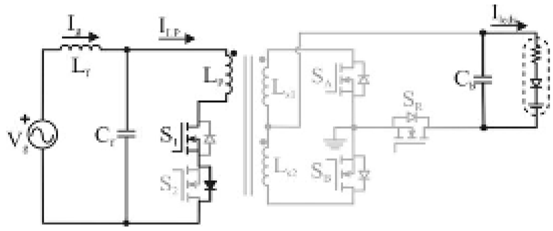

Fig.3 Stage 1 of rectifier mode

During the first stage (Figure 3) the switch S1 is turned on, biasing direct the diode of the switch S2. This way, the grid voltage (Vg) is applied to LP winding, occurring the energy storage in the magnetic coupling. During this stage the bus capacitor (Cb) is responsible for supplying the LEDs.

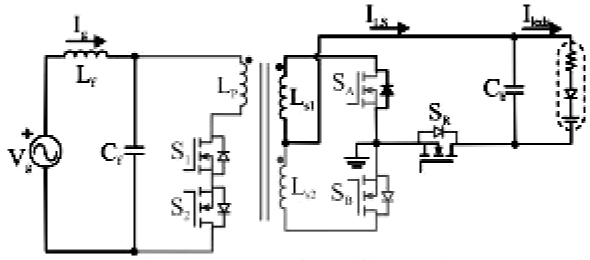

Fig.4 Stage 2 of rectifier mode

The second stage, presented in figure 4, starts at the instant that S1 is turned off and SR is turned on. Thus, it occurs the discharge of the stored energy in the magnetic coupling through the load and the bus capacitor.
The third stage starts when inductor LS1 is completely discharged, characterizing the DCM operation of the converter. During this stage, shown in figure 5, the capacitor Cb supplies the LEDs. This stage ends when the switch is turned on again, restarting the first stage of operation.

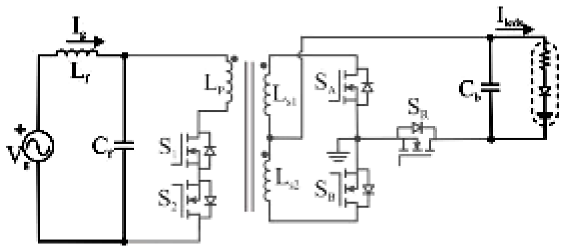

Fig.5 Stage 3 of rectifier mode

INVERTER MODE:

During the inverter mode operation a Sinusoidal Pulse Width Modulation (SPWM) to generate the needed signals to control SA and SB is used..During this positive half-cycle the main switch is SA, while SB remains turned off. The switch SR is turned off during all inverter mode and its intrinsic diode is used for the proper converter operation. The switches S1 and S2 operate at grid frequency (60 Hz).

During the first stage, figure6, the switch SA is turned on. This way, the voltage Vb is applied to the LS1 winding, storing the energy in the magnetic coupling element.

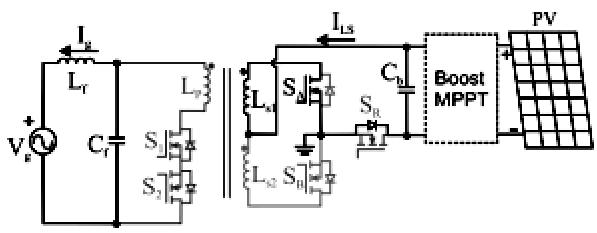

Fig.6 Stage 1 of inverter mode

Second operation stage for the inverter mode begins in the instant that SA is blocked, thus the stored energy is discharged by switch S2 and the diode of the S1 to the grid (Figure 7). During this stage there is no current flow in the windings LS1 and LS2.

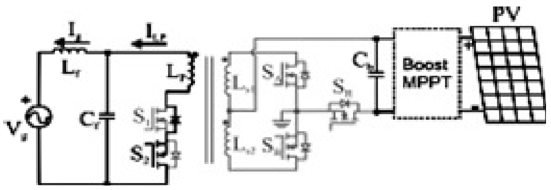

Fig.7 Stage 2 of inverter mode

Figure 8 shows the third operation stage. It begins when the inductor LP is completely discharged, characterizing the DCM operation of the inverter. This stage ends when the main switch, SA, is turned on again, restarting the first stage.

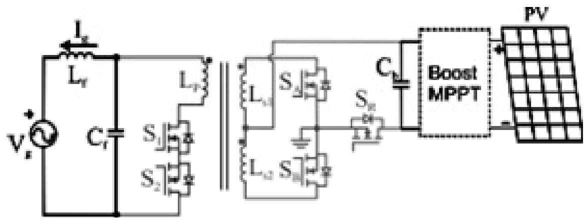

Fig.8 Stage 3 of inverter mode

C. ADVANTAGES OF FLYBACK CONVERTER

- Provides bidirectional flow of energy
- Providing high power factor and low harmonic distortion
- galvanic insulation
- simple structure
- low cost

III.SIMULATION

A.OVERALL MODEL

This section presents the simulation results of the proposed system. To validate the overall performance of the system MATLAB/Simulink is used and simulated.

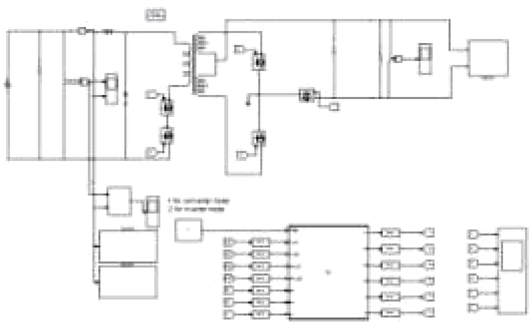

Fig.9 Overall Simulink model

The Simulink model consists of many blocks which are connected to scope to get the waveforms of input and output. The subsystem consists of PV panel with MPPT and breaker which is opened and closed at two modes. The subsystem 2 consists of pulse generation blocks for inverter mode. The subsystem 3 consists of pulse generation blocks for converter mode.

The fcn block consists of all the generated signals and providing output after conversion. This block is used to check whether the system is operating in converter or inverter mode.

B.WAVEFORMS FOR RECTIFIER MODE

Figure 10 shows the waveform of input voltage and current of the system in converter mode of operation.The input voltage of the system in converter mode of operation is 220 V.

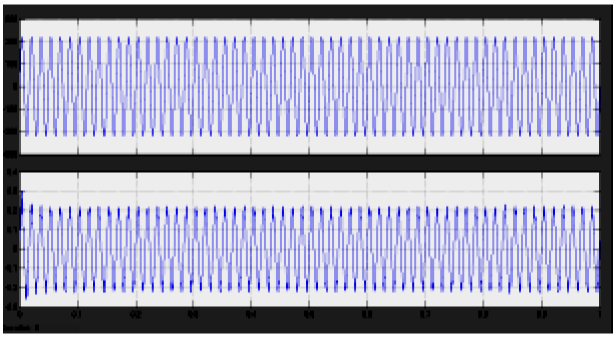

Fig 10 Input voltage and current for rectifier mode

Figure 11 shows the waveform of power factor in converter mode of operation.

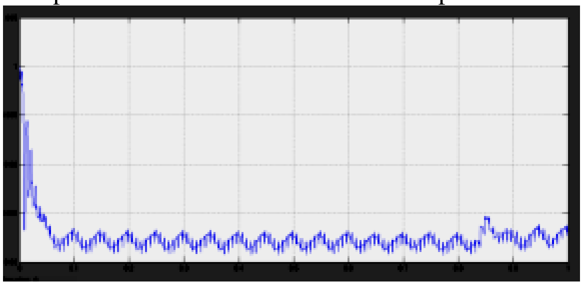

Fig 11 Power factor for rectifier mode

The proposed system produces high power factor which is shown in above waveform and it is 0.98 for rectifier mode.

Figure 12shows the waveform of gate pulses given to all switches in converter mode of operation.

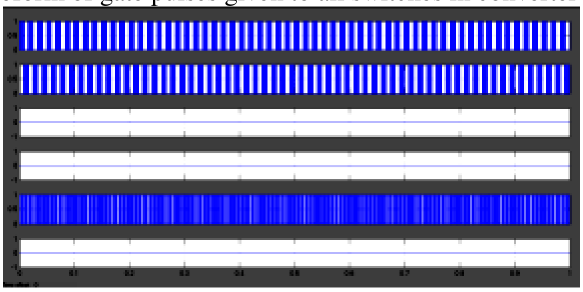

Fig 12 Gate pulses to switches in rectifier mode

Figure 13 shows the output voltage waveform of the system in converter mode of operation.

The output voltage is 58 V in this mode of operation.

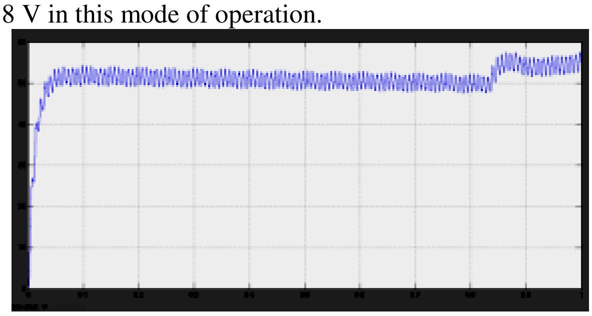

Fig 13 Output voltage in rectifier mode

Table 1 Results for rectifier mode

Symbol	Parameter	Value
THD	Total harmonic distortion	7.43%
PF	Power factor	0.98

C.WAVEFORMS FOR INVERTER MODE

Figure 14 shows the waveform of input voltage and current of the system in inverter mode of operation.

The input voltage of the system in inverter mode of operation is 220 V.

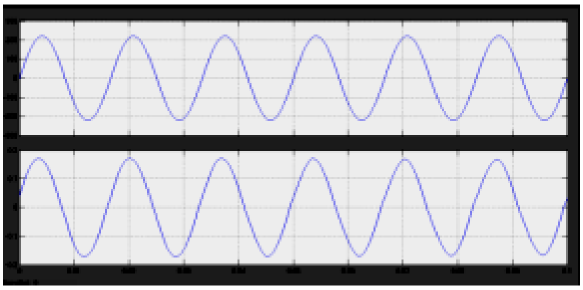

Fig 14 Input voltage and current for inverter mode

Figure 15 shows the waveform of power factor in inverter mode of operation.

The proposed system produces high power factor which is shown in above waveform and it is 0.97 for inverter mode.

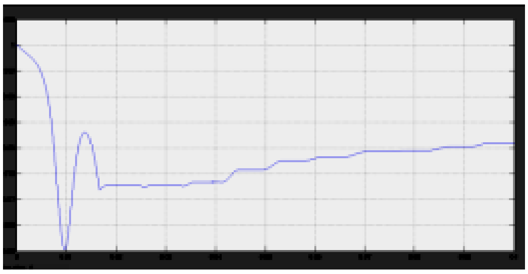

Fig 15 Power factor for inverter mode

Figure 16shows the waveform of gate pulses given to all switches in inverter mode of operation.

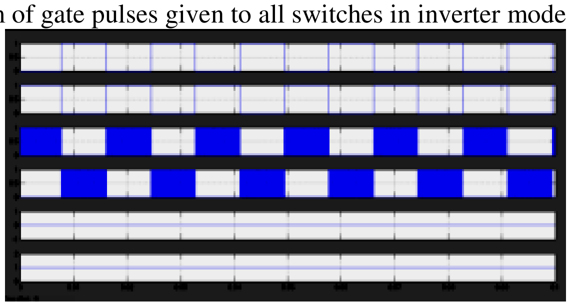

Fig 16 Gate pulses to switches in inverter mode

Figure 17 shows the output voltage waveform of the system in converter mode of operation.

The output voltage is nearly 45 V for this mode of operation.

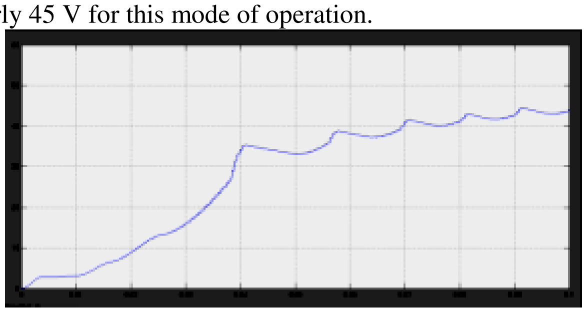

Fig 17 Output voltage in inverter mode

Table 2 Results for inverter mode

Symbol	Parameter	Value
THD	Total harmonic distortion	7.5%
PF	Power factor	0.97

IV HARDWARE IMPLEMENTATION

The main components used in this system areFlybacktransformer(1),LEDs(2),Keypad(3),Microcontroller(4),Relay(5),MPPT converter(6), MOSFET Driver circuit (7),optocoupler(8).

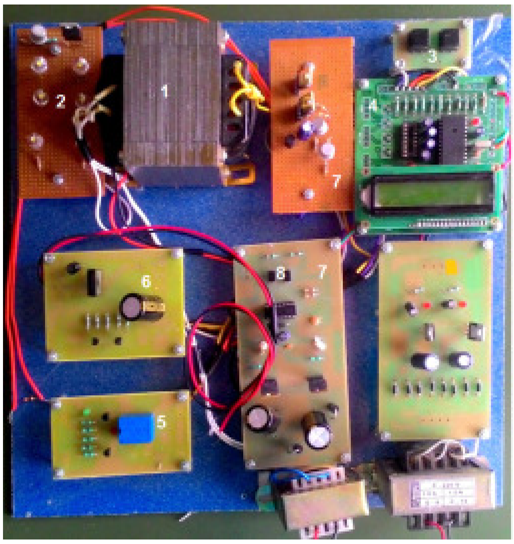

Fig 18 Hardware set-up

Each LED is 1.5 W and here 6 LEDs are used.The keypad is used so that switching through modes can be controlled by it and no need of from supply. It is set with two modes of EB mode and panelmode. Display is used to show in which mode it is operating.

The microcontroller used here is PIC16F877A.The microcontroller are driven via the driver circuit so as to boost the voltage triggering signal to 9V.To avoid any damage to micro controller due to direct passing of 230V supply to it we provide an isolator in the form of opto-coupler in the same driver circuit.

The micro controller section generates the 5 V pulse signal that fed to the driver circuit. The driver circuit converts the 5 V pulse into the 12 V gate pulse. The driver circuit has two sections ,opto-coupler and Darlington pair.

Table 3 Hardware specifications

COMPONENT	SPECIFICATION
MOSFET	IRF 840
MOSFET driver IC	IR 2100
RELAY	12 V
LED	1.5 W
Microcontroller	PIC16F877A
MOSFET in MPPT converter	IRF 250
optocoupler	4D817

For testing the prototype in solar mode, here instead of panel, RPS is used and it is set with voltage of 12 V as shown in figure 19.

Fig.19 Solar mode input

The prototype is coupled to CRO to view the waveform and output values

The panel voltage waveform will be as shown in Fig 20 for solar mode. The output voltage waveform will be as shown in figure 21.

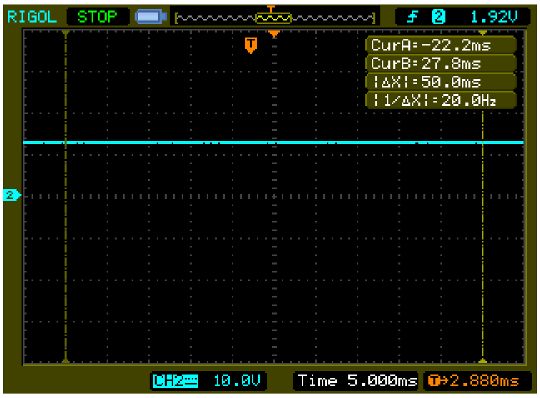

Fig 20 Panel voltage waveform

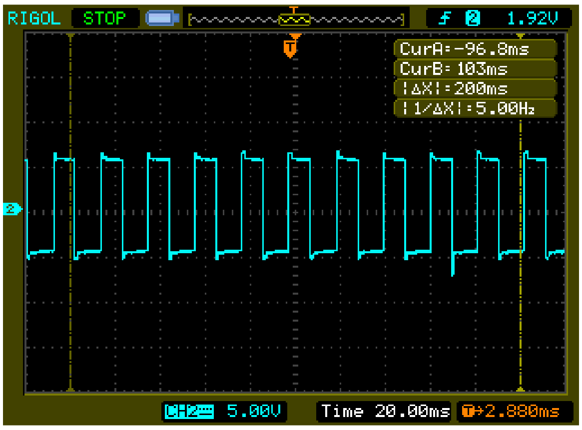

Fig.21 AC output waveform

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V CONCLUSION

This project presents the bidirectional Flyback converter, based on the integration of two Flyback converters, aiming to remove the bridge rectifier input and provide a bidirectional flow of energy. The Flyback converter was chosen for this application because it is widely used in the literature for both systems, distributed generation and for lighting systems based on LEDs.

. The main advantages of this converter are the galvanic insulation, simple structure, low cost and high efficiency. The bidirectional Flyback converter operates in DCM for both modes providing high power factor and low harmonic distortion of the grid current.

Through simulation it is observed that both modes operated with high power factor: 0.98 for rectifier mode and 0.97 for the inverter mode, and reduced total harmonic distortion, 7.43% for rectifier mode and 7.50% for inverter mode. The future extensions can be analysis of the effects of harmonics in the grid voltage, variations in characteristics of PV/LEDs through time,etc.

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