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Implementation of New Control Technique for Interleaved Flyback Inverter Based PV System

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***Abstract*— Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic (PV) power generation has become one of the main ways to use solar energy. And the renewable energy source based distributed generation (DG) system are normally interfaced to the grid through power electronic converters or inverters. An interleaved flyback inverter based photovoltaic system with an improved control strategy is discussed in this paper. A photovoltaic AC module system is considered for study. In a conventional single flyback inverter for the photovoltaic AC module system, this inverter has drawbacks of a conduction losses of each switch, transformer copper and high ripple current of capacitor. To overcome these problems, two flyback converter modules with interleaved pulse-width modulation (PWM) are connected in parallel at the input and output sides reducing the ripple current on the input and output capacitors and decrease the current stress on the transformer windings. In order to verify these, theoretical analysis and simulation are performed. The Matlab/Simulink based simulation demonstrate the betterment of the proposed scheme.**

***Keywords*— PV, PWM, DG, ILFI**

I. INTRODUCTION

Generally Photovoltaic (PV) energy has plays the major role in the renewable energy. The PV technique also grown faster even though the initial cost is high but the solar energy is available at free of cost by naturally and its efficiency also high. To obtain the sufficient power the PV system use the PV modules are connected in series or parallel.

By means of mismatch between the modules, shadows from trees or tree branches, buildings and other things partially cover the PV module so the conventional PV system having power losses. To overcome this problem photovoltaic AC module is considered, For the photovoltaic AC module flyback inverter is the best for the grid connection because it having advantages of less components, simple in construction and provide the isolation between the PV modules and grid line.

Interleaved flyback inverter (ILFI) is basically design for to get the maximum power from the PV module. Normally the conventional flyback inverter having the voltage spike across the main switch. For reducing the voltage spike across the main switch the active clamp circuit is used. The clamp circuit is also used to reduce the switching loss because the main switch is operate with soft switching. By using of the interleaved technique in the inverter the conduction loss of each switch can me minimized, reliability, system life is improved, the ripple current is reduced by the capacitor.

II. SYSTEM STRUCTURE AND ANALYSIS

A. BLOCK DIAGRAM

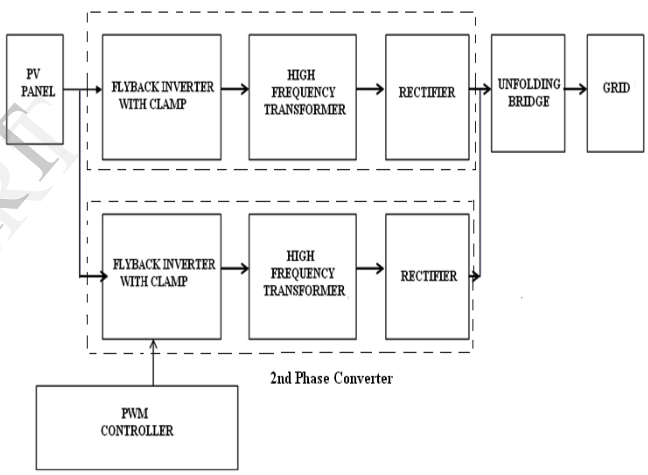


Fig 1. Block diagram for ILFI

B. CIRCUIT CONFIGURATION AND DESCRIPTION

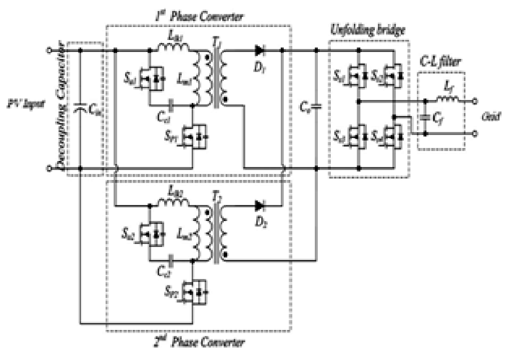


Fig 2. Interleaved flyback inverter for photovoltaic AC module

Interleaved flyback inverter for photovoltaic AC module consists of the PV module as input, decoupling capacitor, 1st phase converter, 2nd phase converter, unfolding bridge and C-L filter. For the Photovoltaic AC system, Maximum Power

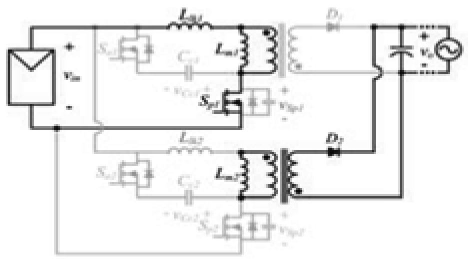
Point Tracking (MPPT) is essential to get the peak power from the PV module. Decoupling capacitor is used to remove the harmonic frequency which distorts the constant PV voltage and current. Both the flyback converters consist of main switches, active clamp circuit, Transformer and Diode.

The active clamp circuit is used to reduce the voltage spike across the main switch which is occurring in resonance between output capacitor and leakage inductance. Transformer is used to maintaining the isolation between PV module and grid line and also boost the voltage. Unfolding bridge is used for connection between transformer and grid line.

C. MODES OF OPERATION

The ILFI having ten operational modes in the switching period, Based on its steady state operation. Due to simplicity of control here considered only discontinuous conduction mode (DCM).

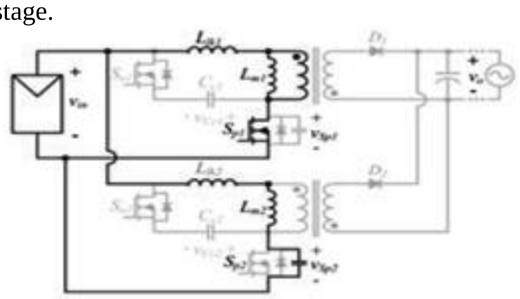
The following modes are shows the steady state operation of ILFI.



(a) Mode 1 [t_0-t_1]

Mode 1 [t_0-t_1]: In a 1st flyback converter stage, main switch S_{p1} is turned on and the auxiliary switch S_{a1} is turned off. The energy is stored to the magnetizing inductor L_{m1} and the primary current i_{Sp1} increases linearly.

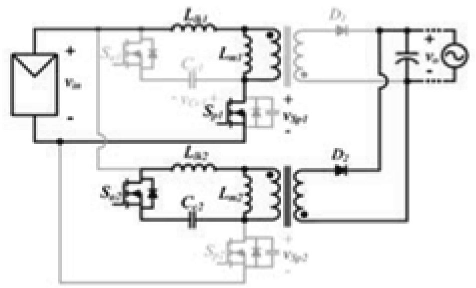
In a 2nd flyback converter stage, the current through leakage inductance L_{Lk2} is zero and the anti-paralleled diode of S_{a2} is turned off. And, the output diode D_2 is turned on. The magnetizing energy in L_{m2} is transferred to the unfolding bridge stage.



(b) Mode 2 [t_1-t_2]

Mode 2 [t_1-t_2]: The switches of 1st flyback converter stage operate in the same with earlier mode.

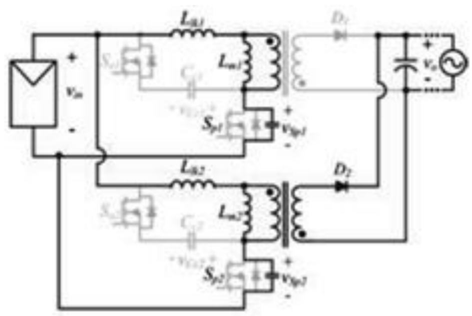
In a 2nd flyback converter stage, magnetizing current i_{Lm2} decreased to zero, and output diode D_2 is turned off. A parasitic resonance occurs between L_{m2} and C_{oss2} of S_{p2}.



(c) Mode 3 [t_2-t_3]

Mode 3 [t_2-t_3]: The switches of 1st flyback converter stage operate in the same with earlier mode.

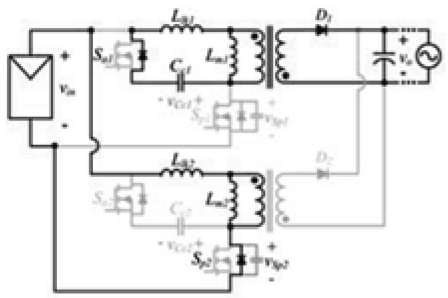
In a 2nd flyback converter stage, auxiliary switch S_{a2} is turned on. The output diode of D_2 is turned on. In the absorbed leakage energy in clamp capacitor C_{c2} is transferred to the unfolding bridge stage. The magnetizing current i_{Lm2} increases reversely too, but the magnitude may be smaller than the leakage current.



(d) Mode 4 [t_3-t_4]

Mode 4 [t_3-t_4]: In a 1st flyback converter stage, the main switch S_{p1} is turned off, the output capacitor of S_{p1} is charged up by the current of magnetizing inductor L_{m1}. The voltage v_{Sp1} across main switch S_{p1} increases linearly. The voltage v_{Sp1} reaches the input voltage v_{in} adds the clamp voltage ($vc1 = vin+vc1$). Due to the large clamp capacitor, the voltage spike caused by resonance between leakage inductance L_{Lk1} and output capacitance across main switch S_{p1} is reduced.

In a 2nd flyback converter stage, the auxiliary switch S_{a2} is turned off. The negative current i_{Sp2} discharges the output capacitor across S_{p2}. When the leakage energy in L_{Lk2} is larger than the energy in output capacitor across S_{p2}, the output diode D_2 keeps on, the difference between i_{Sp2} and i_{Lm2} is fed to the unfolding bridge stage. Once the leakage energy is smaller than the output capacitor across S_{p2}, the magnetizing inductor L_{m2} also helps to realize the soft switching. As soon as the leakage inductor current i_{Sp2} reaches i_{Lm2}, the output diode D_2 is turned off.

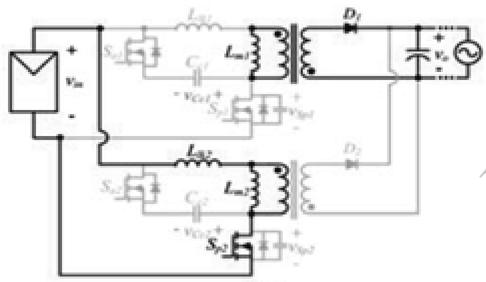


(e) Mode 5 [t_4-t_5]

Mode 5 [t_4-t_5]: In a 1st flyback converter stage, the anti-parallel diode of main switch S_{p1} and the output diode D_1 are turned on. The energy stored in the magnetizing inductor L_{m1} start to emit to the unfolding bridge stage. And the energy in the leakage inductor L_{Lk1} is absorbed by the clamp capacitor C_{c1}.

In this mode, the difference between the magnetizing current i_{Lm1} and primary current i_{Sp1} is transferred to unfolding bridge stage. When the current of leakage inductance i_{Lk1} reaches zero, this mode is finished.

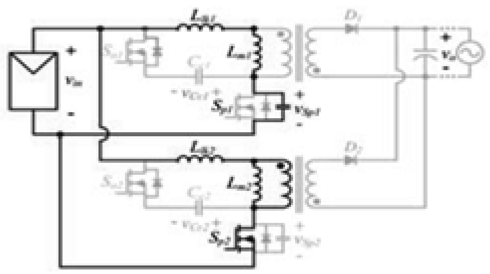
In the 2nd flyback converter stage, the output capacitor voltage across main switch S_{p2} decreased to zero and the anti-parallel diode across main switch S_{p2} is turned on. So, the main switch S_{p2} can be turned on with the soft-switching.



(f) Mode 6 [t_5-t_6]

Mode 6 [t_5 -t_6]: In a 1st flyback converter stage, the current through leakage inductance L_{Lk1} is zero and the anti-paralleled diode of S_{a1} is turned off. And, the output diode D_1 is turned on. The magnetizing energy in L_{m1} is transferred to the unfolding bridge stage.

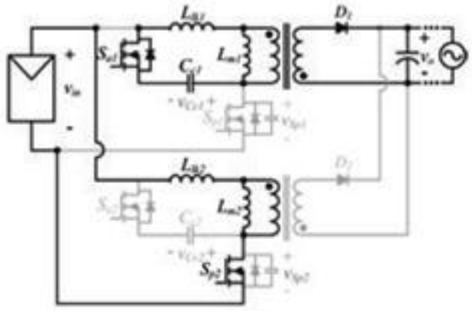
In a 2nd flyback converter stage, main switch S_{p2} is turned on and the auxiliary switch S_{a2} is turned off. The energy is stored to the magnetizing inductor L_{m2} and the primary current i_{Sp2} increases linearly.



(g) Mode 7 [t_6-t_7]

Mode 7 [t_6-t_7]: The switches of 1st flyback converter stage, magnetizing current i_{Lm1} decreased to zero, and output diode D_1 is turned off. A parasitic resonance occurs between L_{m1} and C_{oss1} of S_{p1}.

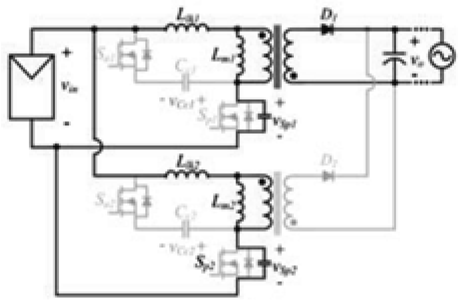
In a 2nd flyback converter stage, operate in the same with earlier mode.



(h) Mode 8 [t_7-t_8]

Mode 8 [t_7-t_8]: The switches of 1st flyback converter stage, auxiliary switch S_{a1} is turned on. The output diode of D_1 is turned on. In the absorbed leakage energy in clamp capacitor C_{c1} is transferred to the unfolding bridge stage. The magnetizing current i_{Lm1} increases reversely too, but the magnitude may be smaller than the leakage current.

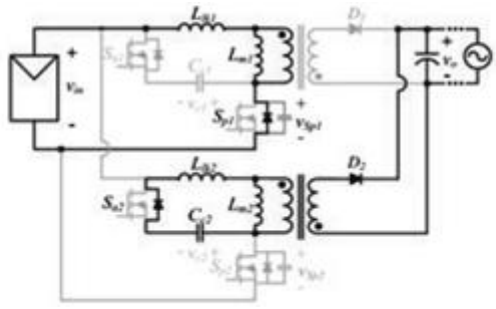
In a 2nd flyback converter stage, operate in the same with earlier mode.



(i) Mode 9 [t_8-t_9]

Mode 9 [t_8-t_9]: In a 1st flyback converter stage, the auxiliary switch *Sa1* is turned off. The negative current i_{Sp1} discharges the output capacitor across S_{p1}. When the leakage energy in L_{Lk1} is larger than the energy in output capacitor across S_{p1}, the output diode D_1 keeps on, the difference between i_{Sp1} and i_{Lm1} is fed to the unfolding bridge stage. Once the leakage energy is smaller than the output capacitor across S_{p1}, the magnetizing inductor L_{m1} also helps to realize the soft switching. As soon as the leakage inductor current i_{Sp1} reaches i_{Lm1}, the output diode D_1 is turned off.

In a 2nd flyback converter stage, the main switch S_{p2} is turned off, the output capacitor of S_{p2} is charged up by the current of magnetizing inductor L_{m2}. The voltage v_{Sp2} across main switch S_{p2} increases linearly. The voltage v_{S2} reaches the input voltage v_{in} adds the clamp voltage v_{c2} (= v_{in}+v_{c2}). Due to the large clamp capacitor, the voltage spike caused by resonance between leakage inductance L_{Lk2} and output capacitance across main switch S_{p2} is reduced.



(j) Mode 10 [t_9-t_{10}]

Mode 10 [t_9-t_{10}]: In a 1st flyback converter stage, the output capacitor voltage across main switch S_{p1} decreased to zero and the anti-parallel diode across main switch S_{p1} is turned on. So, the main switch S_{p1} can be turned on with the soft-switching

In the 2nd flyback converter stage, the anti-parallel diode of main switch S_{p2} and the output diode D_2 are turned on. The energy stored in the magnetizing inductor L_{m2} start to emit to the unfolding bridge stage. And the energy in the leakage inductor L_{Lk2} is absorbed by the clamp capacitor C_{c2}. In this mode, the difference between the magnetizing current i_{Lm2} and primary current i_{Sp2} is transferred to unfolding bridge stage. When the current of leakage inductance i_{Lk2} reaches zero, this mode is finished.

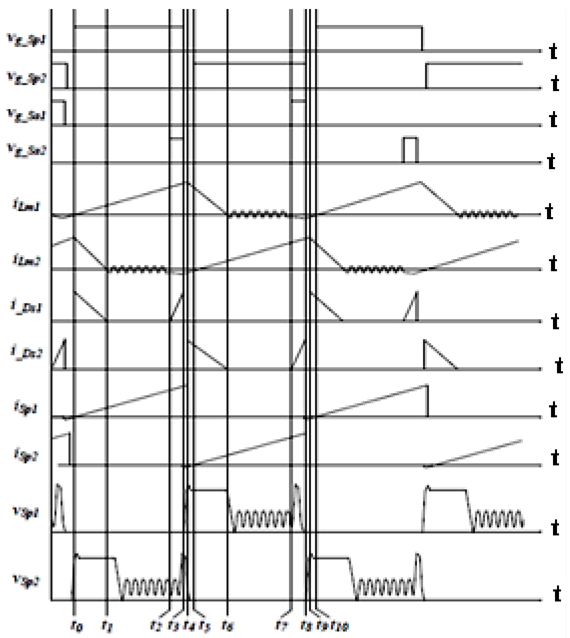


Fig 3. Steady state operation waveform of ILFI

III. ACTIVE CLAMP CONTROL TECHNIQUE

A. Without the active clamp circuit:

When the main switch S_{p1} is turned off, the voltage across S_{p1} is sum of the input voltage, feedback voltage and voltage spike which is cause by means of resonance between the leakage inductance L_{lk1} and output capacitance C_{oss} of the S_{p1}. When the voltage spike of S_{p1} increased over the rating then the S_{p1} has to fail. For reducing this voltage spike of the main switch S_{p1} the active clamp circuit is used.

B. With active clamp circuit:

When using the active clamp circuit the leakage energy will be absorbed by the clamp capacitor C_{c1}. Hence the voltage spike across the main switch S_{p1} can be reduced. So during the grid period the ILFI operates stable due to the small voltage across the main switch S_{p1} than its rating.

IV. MAXIMUM POWER POINT TRACKING

MPPT charge controller is a maximum power point tracker which is an electronic DC to DC converter which takes the DC input from the solar panels, changes it to high frequency AC and converts it back to a different DC current to match with the batteries.

A. DIFFERENT MPPT ALGORITHM

The different types of algorithms which are used for finding MPPT of the solar panel are

CONVENTIONAL ALGORITHMS

- Perturb & Observe
- Incremental conductance
- Constant voltage method
- Constant current method

B. PRINCIPLE OF P&O

If the operating current or, in other words, the current drawn from the PV array is perturbed in a given direction and if the power drawn from the PV array increases, the operating point becomes closer to the MPP and, thus, the operating current should be further perturbed in the same direction.

If the current is perturbed and this results in a decrease in the power drawn from the PV array, this means that the point of operation is moving away from the MPP and therefore, the perturbation of the operating current should be reversed.

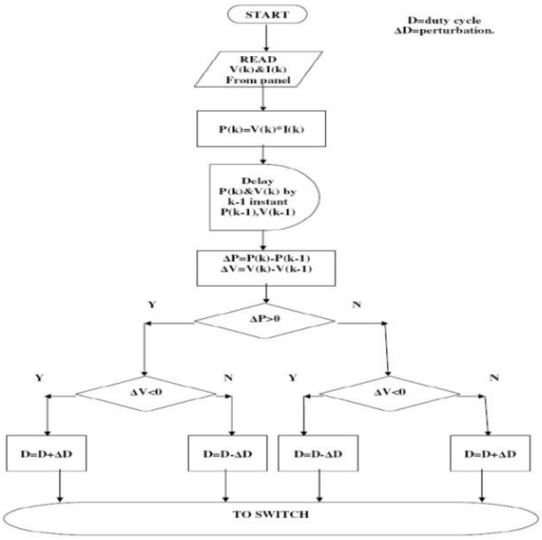


Fig 4. Flow chart of the P&O technique

TABLE I

Design parameter of ILFI

PARAMETER	VALUE	UNIT
Grid Frequency f_{grid}	50	Hz
Input Capacitance C_{in}	11	mF
DC link Capacitance C_o	136	nF
Leakage Inductance L_{lk1},L_{lk2}	0.21	μH
Transformer Turns Ratio	1:6	-
Magnetizing Inductance L_{m1},L_{m2}	8.28	μH
Filter Capacitance C_f	25	μF
Filter Inductance L_f	3	mH

V. ILFI SIMULINK MODEL

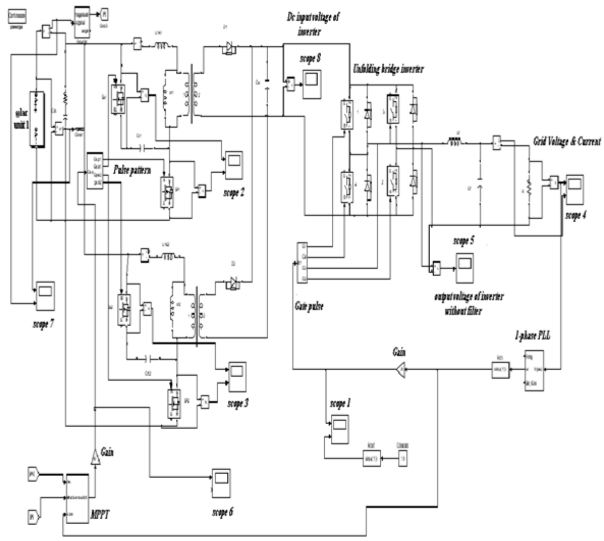


Fig 5. Simulation diagram for ILFI

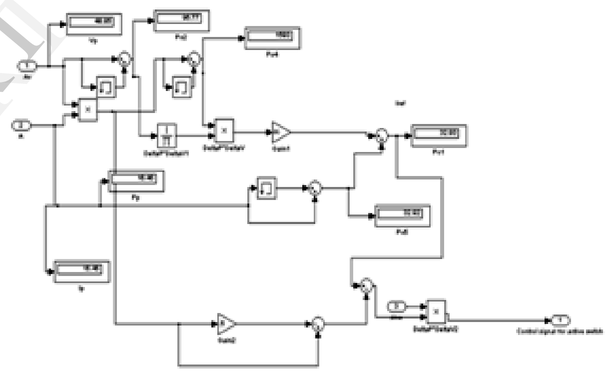


Fig 6. Simulation diagram for MPPT block

VI. SIMULATION RESULTS

The simulation results are produced with MATLAB 2009b. The result shows the waveforms for voltage and current across PV panel. Also, the gate pulses of each switches, voltage across the main switch and active clamp switch, DC input voltage for the inverter, inverter output voltage without filter and grid voltage, grid current.

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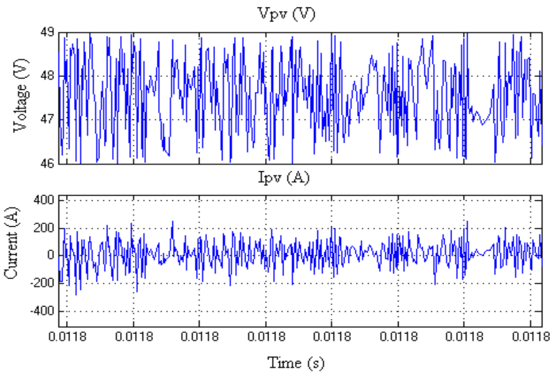

Fig 7. voltage and current across PV panel

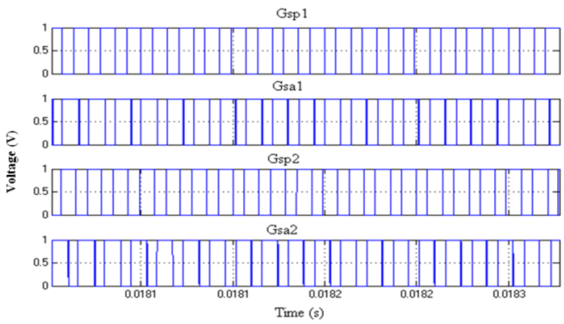

Fig 8. Gate pulses of each switches

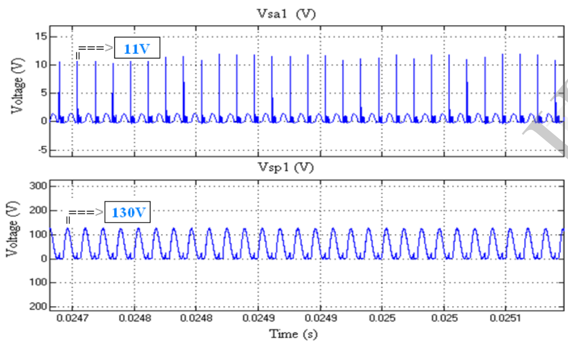

Fig 9. Voltage across switch Sa1, Sp1

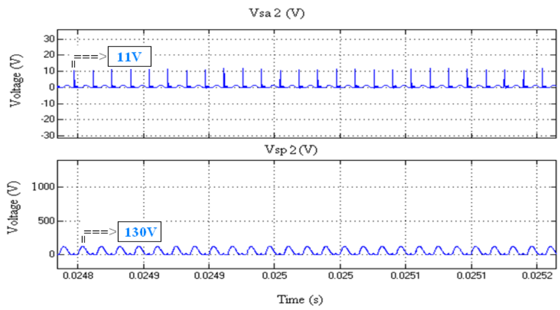

Fig 10. Voltage across switch Sa2, Sp2

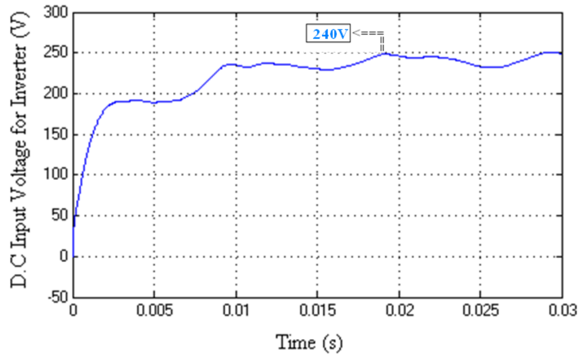

Fig 11. DC input voltage for the inverter

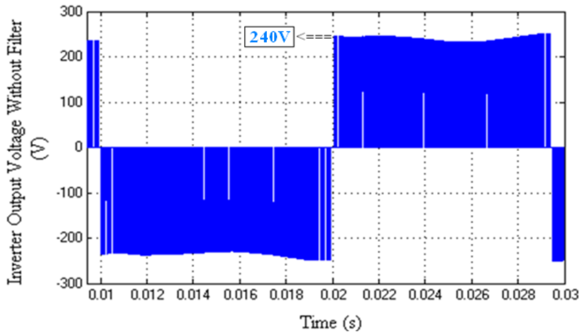

Fig 12. Inverter output voltage without filter

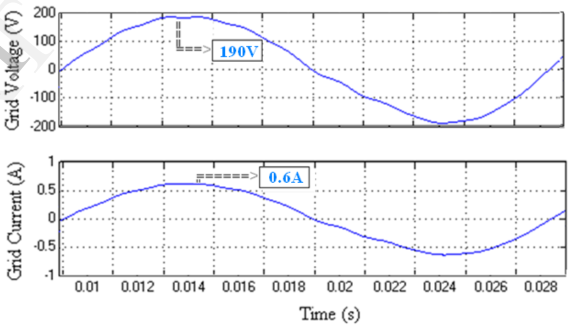

Fig 13. Grid voltage and Grid current

VII. CONCLUSION

The flyback inverter has become an unavoidable component. Because it having the advantages of fewer components, simplicity in construction, Isolation between the PV modules and the grid line. By using the interleaved technique in the flyback inverter the conduction loss of each switch can be reduced. The ILFI being practice in renewable energy system. A flyback inverter based energy efficient PV system has been developed. The system consist of transformer, diode rectifier, unfolding bridge, filter, etc. The working of the system with mode diagram has been presented. The crux of the system, active clamp control technique helps in energy efficient operation through the power loss. The ILFI based PV system is modeled in the MATLAB simulink and the results are verified. In this the Perturb & Observe algorithm is used in the PV to get the maximum power. The proposed flyback inverter system characteristics are analysed with the help of waveforms.

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